ANNA UNIVERSITY

NON-AUTONOMOUS COLLEGE

AFFILIATED TO ANNA UNIVERSITY

M.E., POWER SYSTEMS ENGINEERING

REGULATIONS 2025

PROGRAMME OUTCOMES (POs)

On successful completion of the programme, the graduate would have	
PO1	An ability to independently carry out research / investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report / document.
PO3	Students should be able to demonstrate a degree of mastery in power systems engineering.

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of Electrical and Electronics Engineering program, the student will have the following Program Specific Outcomes.	
PSO1	Get elevated as technically competent Power Engineer to cater the needs of Electrical Power Industry, Research and Educational Institutions. Pursue career in core service sector of power system industry with life long learning and professional ethics.
PSO2	Become an entrepreneur in modern restructured power systems, proficient in application software packages used in the Power System industry.

ANNA UNIVERSITY, CHENNAI

POST GRADUATE CURRICULUM (NON.AUTONOMOUS AFFILIATED INSTITUTIONS)

Programme: M.E., Power Systems Engineering **Regulations:** 2025

Abbreviations:

BS – Basic Science (Mathematics, Physics, Chemistry)
ES – Engineering Science (General (**G**), Programme Core (**PC**), Programme Elective (**PE**))
SD – Skill Development
SL – Self Learning
OE – Open Elective

L –Laboratory Course
T – Theory
LIT –Laboratory Integrated Theory
PW – Project Work
TCP –Total Contact Period(s)

Semester I

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	PS25101	Power System Dynamics	LIT	2	1	2	5	4	ES (PC)
2.	PS25102	Advanced Power System Analysis	LIT	2	1	2	5	4	ES (PC)
3.	PS25103	Advanced Power System Operation and Control	LIT	2	1	2	5	4	ES (PC)
4.	PX25C01	Analysis of Power Converters	LIT	3	0	2	5	4	ES (PC)
5.	PS25104	Power System Instrumentation	T	3	0	0	3	3	ES (PC)
6.	PS25105	Technical Seminar	-	0	0	2	2	1	SD
Total Credits							**25**	**20**	

Semester II

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	PS25201	High Voltage DC Transmission	T	3	0	0	3	3	ES (PC)
2.	PS25202	Advanced Power System Protection	LIT	3	0	2	5	4	ES (PC)
3.	PS25203	Power System Restructuring and Pricing	T	3	0	0	3	3	ES (PC)
4.	PS25204	Smart Power Grid Technologies	T	3	0	0	3	3	ES (PC)
5.	---	Programme Elective I	T	3	0	0	3	3	ES (PE)
6.	---	Industry Oriented Course I	---	1	0	0	1	1	SD
7.	PS25205	Industrial Training	---	---	---	---	---	2	SD
8.	---	Self-Learning Courses	--	--	-	--	--	1	SD
Total Credits							**18**	**20**	

Semester III

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	---	Programme Elective II	T	3	0	0	3	3	ES (PE)
2.	---	Programme Elective III	T	3	0	0	3	3	ES (PE)
3.	---	Programme Elective IV	T	3	0	0	3	3	ES (PE)
4.	---	Open Elective	--	3	0	0	3	3	-
5.	---	Industry Oriented Course II	---	1	0	0	1	1	SD
6.	PS25301	Project Work I	---	0	0	12	12	6	SD
Total Credits							**25**	**19**	

Semester IV

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	PS25401	Project Work II	---	0	0	24	24	12	SD
Total Credits							**24**	**12**	

Programme Elective Courses (PE)

S. No.	Course Code	Course Title	Periods			Total Contact Periods	Credits
			L	T	P		
1.	PX25C04	Wind Energy Conversion systems	3	0	0	3	3
2.	PS25001	Analysis of Electrical Machinery	3	0	0	3	3
3.	PS25002	Inverter-Based Renewable Energy systems	3	0	0	3	3
4.	PX25C02	Electric Vehicles and Power Management	3	0	0	3	3
5.	PS25003	Energy Auditing and Management	3	0	0	3	3
6.	PS25004	Electrical Distribution Systems	3	0	0	3	3
7.	PS25005	IoT for Smart Energy Management Systems	3	0	0	3	3
8.	PX25C03	Power Quality	3	0	0	3	3
9.	PS25006	System Theory	3	0	0	3	3
10.	PS25007	Advanced Power System Dynamics	3	0	0	3	3
11.	PS25008	Power System Planning and Reliability	3	0	0	3	3
12.	PS25C01	Distributed Generation and Micro-Grids	3	0	0	3	3
13.	PS25009	Power System Transients	3	0	0	3	3
14.	PS25010	Graph Theory applications to power systems	3	0	0	3	3
15.	PS25011	Design of Solar PV Systems	3	0	0	3	3
16.	PS25012	Big Data Analytics in Power Systems	3	0	0	3	3
17.	PS25C02	FACTS	3	0	0	3	3
18.	PS25013	Application of AI Techniques to Power System	3	0	0	3	3
19.	PS25014	Cybersecurity of Smart Grids	3	0	0	3	3
20.	PS25015	Grid Compliance Study of Inverter Based Resources	3	0	0	3	3
21.	PS25016	Energy Storage Technologies	3	0	0	3	3

Semester I

PS25101	Power System Dynamics	L	T	P	C
		2	1	2	4

Course Objective:

To introduce the dynamic behaviour of power systems under small and large disturbances. To model synchronous machines, exciters, and loads for dynamic studies. To analyse transient and small-signal stability in interconnected systems. To use modern simulation tools for dynamic performance analysis. To explore techniques for stability enhancement in practical power systems.

Introduction to Power System Dynamics: Need for dynamic analysis in power systems- Stability concepts: steady-state, transient, small-signal, voltage, frequency- Mathematical preliminaries: nonlinear system behaviour, equilibrium points, stability definitions- Review of numerical methods for stability studies.

Activity: MATLAB/Python simulation of swing equation for a single machine connected to infinite bus (SMIB).

Synchronous Machine Modelling: Classical model and its limitations- Park's transformation, d–q axis equations- Modelling of synchronous machines with and without damper windings- Turbine-governor and load modelling (static & dynamic).
Activity: Build and simulate a synchronous machine model in MATLAB/Simulink.

Excitation Systems: Excitation system requirements and IEEE models- Effect of excitation on power system stability- Static & dynamic load models.
Activity: Simulate the AVR model

Small Signal Stability Analysis: Small-signal stability of SMIB and multimachine systems-Damping and synchronizing torque concepts-Eigenvalue analysis and participation factors-Effect of Field circuit dynamics-Effect of AVR dynamics- Power System Stabilizers (PSS) design and application.

Activity: Eigenvalue and participation factor analysis of SMIB system.

Transient Stability: Transient stability studies – equal area criterion- Numerical integration methods: step-by-step, modified Euler, Runge-Kutta- Critical clearing time and angle- Stability enhancement methods: fast valving, braking resistors, high-speed excitation- Case studies with renewables and inverter-based systems.
Activity: Transient stability simulation of a multi-machine system under fault conditions.

Laboratory Practice:

1. Determination of synchronous machine parameters in SMIB system, Swing equation calculations in SMIB system under different conditions.
2. Simulation of steam turbine governor model, Simulation of hydraulic turbine governor model.
3. Simulation of DC, AC and IEEE excitation systems

4. Simulation of small signal stability analysis of classical SMIB system,
5. Simulation of small signal stability analysis of SMIB system including field flux.
6. Simulation of modal and eigen value analysis in power system.
7. Simulation of small signal stability analysis in SMIB including AVR and PSS

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).

References:

1. P. Kundur, Power System Stability and Control, McGraw Hill, 1994.
2. K.R. Padiyar, Power System Dynamics: Stability and Control, BS Publications, 2002.
3. P.M. Anderson & A.A. Fouad, Power System Control and Stability, IEEE Press.
4. Machowski, Bialek, Bumby, Power System Dynamics: Stability and Control, Wiley, 2020.
5. IEEE Committee Reports on Excitation Systems and Stabilizers.

Web References

1. NPTEL – Power System Dynamics: https://nptel.ac.in/courses/108/101/108101127/
2. MathWorks – Power System Stability Examples:
3. https://in.mathworks.com/help/physmod/sps/powersys/ref/powersystemstability.html
4. IEEE PES Resource Center: https://resourcecenter.ieee-pes.org
5. CIGRÉ Technical Publications: https://www.cigre.org/publications
6. PSCAD/DIgSILENT Tutorials: https://hvdc.ca/pscad/, https://www.digsilent.de/en/tutorials.html

	Description of CO	POs	PSO1	PSO2
CO1:	Ability to Explain the need and fundamentals of power system dynamics and stability.	PO1(3) PO2(1) PO3(3)	3	2
CO2:	Ability to Develop models of synchronous machines, exciters, and loads for system studies	PO1(3) PO2(1) PO3(3)	3	3
CO3:	Ability to Perform small-signal stability analysis using eigenvalue methods.	PO1(3) PO2(1) PO3(3)	3	2
CO4:	Ability to Evaluate transient stability and propose enhancement techniques.	PO1(3) PO2(2) PO3(3)	3	3
CO5:	Ability to Apply simulation tools for analyzing dynamic performance of power systems.	PO1(3) PO2(2) PO3(3)	3	2

PS25102	Advanced Power System Analysis	L	T	P	C
		2	1	2	4

Course Objective:

This course aims

- To enable the students to analyse the mathematical representation of power system components and solution techniques and generalise the power flow analysis using various methods.
- To infer the knowledge of the different types of faults and its calculation using computer method and mathematical model.
- To know the concept of numerical integration methods to analyse power system transient stability.

Solution Techniques: Sparse matrix techniques for large scale power systems: Optimal ordering schemes for preserving sparsity, Flexible packed storage scheme for storing matrix as compact arrays, Factorization by Bifactorization and Gauss elimination methods, repeat solution using left and right factors and L and U matrices.

Activity: Group Discussion on Gauss Elimination Method

Power Flow Analysis: Fast decoupled power flow method, Sensitivity factors for P-V bus adjustment, Net interchange power control in multi-area power flow analysis: ATC, assessment of available transfer capability (ATC) using repeated power flow method, Continuation power flow method - Contingency analysis.

Activity: Quiz: Available transfer capability

Optimal Power Flow: Problem statement - Solution of optimal power flow (OPF), The gradient method, Newton's method, linear sensitivity analysis; LP methods with real power variables only, LP method with AC power flow variables and detailed cost functions, security constrained optimal power flow - Interior point algorithm - Bus Incremental costs.

Activity: Quiz: Interior Point Algorithm

Short Circuit Analysis: Fault calculations using sequence networks for different types of faults, Bus impedance matrix (ZBUS) construction using building algorithm for lines with mutual coupling, Simple numerical problems, Computer method for fault analysis using ZBUS and sequence components, Derivation of equations for bus voltages, fault current and line currents, both in sequence and phase domain using Thevenin's equivalent and ZBUS matrix for different faults.

Activity: Group Discussion on Computer method for fault analysis.

Transient Stability Analysis: Introduction, numerical integration methods: Euler and fourth order Runge, Kutta methods, algorithm for simulation of SMIB and multi-machine system with classical synchronous machine model, Factors influencing transient stability, numerical stability and implicit integration methods.

Activity: Group Discussion on Factors influencing transient stability

Laboratory Exercises:

1. Simulation of large-scale power system to determine the voltage magnitudes and phase angles at different points in the system.
2. Simulation of Load flow study of a power transmission network.
3. Simulation ofLoad flow study of a radial distribution network.
4. Simulation of large-scale power system to perform Short Circuit studies according to IEC 60909, ANSI, and GOST standards.

5. Simulation of large-scale power system to assess the system's transient ability to maintain synchronism after disturbances.

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).

References:

1. Grainger, J.D., “Power System Analysis”, Tata McGraw Hill Publishing Company, 2016.
2. Kusic, C.L.,“Computer Aided Power System Analysis” , Tata McGraw Hill Publishing Company, Reprint 2017.
3. Pai, M. A.,“Computer Techniques in Power System Analysis” , TMH Publishing Company, Reprint 2015.
4. Stagg, G. W. and Elabiad, A. H., “Computer Methods in Power System Analysis” McGraw Hill, Reprint 2016.
5. Wood, A.J. and Wollenberg, B.F.,“Power Generation, Operation and Control” , John Wiley and Sons, 2015.
6. Singh L.P.,“Advanced power system analysis and dynamics” , 3rd Ed., Wiley eastern, New Delhi, 2015.

	Description of CO	**PO**	**PSO1**	**PSO2**
CO1	Analyze large-scale power systems using advanced computational methods and algorithms	PO1(3) PO2(1) PO3(3)	3	2
CO2	Apply advanced methods for steady-state power system analysis under symmetrical and unsymmetrical faults	PO1(3) PO2(1) PO3(3)	3	2
CO3	Formulate and solve equations for AC, DC, and optimal power flow	PO1(3) PO2(1) PO3(3)	3	3
CO4	Utilize modern simulation tools for short-circuit, load flow, and optimal power flow studies	PO1(3) PO2(2) PO3(3)	3	3
CO5	Evaluate the transient stability of power systems under disturbances	PO1(3) PO2(2) PO3(3)	3	2

PS25103	Advanced Power System Operation and Control	L	T	P	C
		2	1	2	4

Course Objective:

To impart the knowledge on various operational and control activities as applied to the power system, articulate the economic nuances and modern control techniques & estimate the states of the power system under normal and abnormal conditions.

Real Power and Frequency Control : Fundamentals of speed governing mechanism and modelling: Speed-load characteristics, Load sharing between two synchronous machines in parallel, LFC of single/multi-area systems- Static and dynamic analysis, economic dispatch, tie-line control, state-variable model.

Activities: Tutorial on ALFC for single and two area systems, load sharing between two synchronous generators

Reactive Power and Voltage Control:Reactive power production/absorption, AVR, shunt/series compensation, Methods of Voltage Control , synchronous condensers, static VAR systems, Modeling of reactive compensating devices, Application of tap changing transformers to transmission systems, Distribution system voltage regulation, Modeling of transformer ULTC control systems.

Activities: Tutorial on AVR with conventional controllers, series and shunt compensation in Power System transmission lines.

Unit Commitment and Economic Dispatch: Statement of Unit Commitment (UC) problem, constraints, Priority List, Dynamic Programming, Lagrangian relaxation,Forward DP approach method- Economic dispatch problem with losses, Lambda-iteration, Gradient method, piecewise linear cost, two generator system, coordination equations, Incremental losses and penalty factors, Hydro Thermal Scheduling using DP.

Activities: Tutorial on UC and ED problems using methods listed above

Modern Control of Power Systems: System operating states, contingency analysis, linear sensitivity factors, Line Outage Sensitivity Factor, Generation Outage Sensitivity Factor, Analysis of multiple contingencies, corrective controls, Energy Control Centre, SCADA system, EMS functions.

Activities: Tutorial on Contingency Analysis for simple power networks

State Estimation: Maximum likelihood Weighted Least Squares Estimation: Concepts, Matrix formulation, Example for Weighted Least Squares state estimation, state estimation of an AC network, Estimation by Orthogonal Decomposition algorithm, Detection and Identification of Bad Measurements, observability, pseudo-measurements, PMU applications.

Activities: Tutorial on State estimation of AC network with PMU.

Laboratory Exercises:

1. Simulation of ALFC for single and two area systems
2. Simulation of AVR with conventional controllers, series and shunt compensation in Power System transmission lines
3. Simulation of UC and ED problems using methods listed above
4. Contingency Analysis for simple power networks
5. Simulation of State estimation of an AC network

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).

References

1. Wood, A. J., & Wollenberg, B. F. (2016). Power generation, operation, and control. John Wiley and Sons.
2. Kundur, P. (2008). Power system stability and control (5th reprint). Tata McGraw Hill.
3. Elgerd, O. I. (2002). Electric energy system theory: An introduction. Tata McGraw Hill.
4. Kothari, D. P., &Nagrath, I. J. (2003). Modern power system analysis (4th ed.). Tata McGraw Hill Publishing Company Limited.
5. Grigsby, L. L. (2001). The electric power engineering handbook. CRC Press & IEEE Press.

	Description of CO	PO	PSO1	PSO2
CO1	Identify the operational activities of power systems under normal operating conditions	PO1(2) PO2(1) PO3(3)	3	2
CO2	Summarize the control activities of power systems under both normal and abnormal operating conditions	PO1(2) PO2(1) PO3(3)	3	2
CO3	Analyze the economic aspects and cost optimization of power system operation	PO1(3) PO2(2) PO3(3)	3	3
CO4	Illustrate and apply modern control techniques in power system operation	PO1(3) PO2(2) PO3(3)	3	3
CO5	Evaluate the operating states of the power system under normal and abnormal conditions	PO1(3) PO2(2) PO3(3)	3	3

PX25C01	Analysis of Power Converters	L	T	P	C
		3	0	2	4

Course Objectives:

- To provide a comprehensive understanding of the operation, design, and control of hard switched and soft switched power electronic converters.
- To analyse and evaluate the performance of single-phase and three-phase power converters under various load conditions.
- To enhance practical skills through laboratory experiments that reinforce theoretical concepts and provide exposure to real-world converter operation and analysis.

Single-Phase Controlled Rectifiers: Semi and fully controlled rectifiers with R, RL, and RLE loads. Freewheeling diode effects: Continuous and discontinuous conduction modes. Inversion operation; Dual converter operation. PWM rectifiers. Performance parameters: Harmonics, ripple, distortion, power factor. Effect of source inductance.

Practical: Simulation and Experimention of single-phase half and fully controlled converters. / Gate drivers and firing circuits for single phase rectifiers./ Waveform analysis under various load conditions./ Input power factor and harmonic analysis.

Three-Phase Controlled Rectifiers: Three-phase semi and fully controlled rectifiers with R, RL, RLE loads. Freewheeling diode, inversion operation, continuous/discontinuous modes. Multi-pulse (6 and 12 pulse) and dual converters. Effect of source inductance and commutation overlap. Performance parameters

Practical: Simulation and Experimentation of three-phase line-commutated converters.

DC-DC Converters: Non-isolated topologies: Buck, Boost, Buck-Boost, Cuk. Isolated topologies: Single and multiple switch converters. Operation in CCM and DCM; Synchronous and interleaved converters.

Practical: Design and testing of driver circuits for DC-DC converters (totem pole/transformer based/boot strap/opto coupler based)

DC-AC Inverters: Single-phase and three-phase VSI and CSI; 120° and 180° conduction modes. PWM techniques: Sine PWM, Space Vector PWM, 60° PWM, Third harmonic PWM. Multilevel inverters: Diode-clamped, flying capacitor, cascaded H-bridge. Voltage control methods and harmonic elimination. Filter design and device selection.

Practical: Simulation and analysis of single phase and three-phase inverters / Generation of PWM pulses with different modulation techniques/ Harmonic spectrum and THD analysis.

AC-AC Converters: AC voltage controllers: Single-phase and three-phase with R, RL loads. Phase angle control and integral cycle control. Working principle of Resonant converters: ZVS, ZCS, quasi, and multi-resonant types.

Practical: Simulation and Experimentation of AC voltage regulators / Simulation and experimentation of resonant converters

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).

References:

1. Rashid, M. H. (2017). *Power electronics: Circuits, devices and applications* (4th ed.). Prentice Hall India.
2. Bose, B. K. (2003). *Modern power electronics and AC drives* (2nd ed.). Pearson Education.
3. Umanand, L. (2010). *Power electronics: Essentials & applications* (1st ed.). Wiley.
4. Mohan, N., Undeland, T. M., & Robbins, W. P. (2007). *Power electronics: Converters, applications and design* (3rd ed.). John Wiley and Sons.
5. Bimbhra, P. S. (2022). *Power electronics* (7th ed.). Khanna Publishers.

E-resources:

1. https://onlinecourses.nptel.ac.in/noc24_ee88/preview.

	Description of CO	PO	PSO1	PSO2
CO1	Analyze the operation and performance of single-phase and three-phase rectifiers under various load conditions.	PO1(3) PO3(3)	3	2
CO2	Design and evaluate isolated and non-isolated DC-DC converter topologies for specific applications.	PO1(2) PO3(2)	3	3
CO3	Implement PWM techniques in single and three-phase inverters and assess performance.	PO1(3) PO3(2)	3	3
CO4	Examine and compare multilevel inverters and resonant converter architectures for high-power applications.	PO1(3) PO2(2) PO3(2)	3	1
CO5	Conduct experiments and simulations to validate theoretical concepts and evaluate real-time converter behaviour.	PO1(3) PO2(2) PO3(3)	3	3

PS25104	Power System Instrumentation	L	T	P	C
		3	0	0	3

Course Objective:

This course aims

- To provide a comprehensive understanding of instrumentation used in power generation, transmission, and distribution systems.
- It focuses on measurements, SCADA, substation and distribution automation, and energy management.
- Emphasis is also placed on modern control techniques and data acquisition systems for efficient and reliable power system operation.

Fundamentals of Power System Instrumentation: Measurement and error analysis - Objective and philosophy of power system instrumentation - Measurement of large currents, high voltages, torque, and speed, Standard specifications for instrumentation - Introduction to data acquisition systems in power systems.

Activities: Group Discussion: Why standard specifications are important in measurement; students discuss in pairs or small groups.

SCADA and Communication in Power Systems: SCADA architecture, components and applications - Data transmission and telemetry - PLC equipment and computer control of power systems - Communication protocols: IEC 60870, IEC 61850 - Man-Machine Interface (HMI)

Activities: Simulation Exercise: Use a SCADA simulation tool (or online demo) where students can observe data from a virtual substation.

Quiz / Concept Check: Short quiz on SCADA terminology, communication protocols, and PLC equipment.

Power Plant Instrumentation: Instrumentation diagram and Measurement of electrical parameters of thermal and nuclear power plants, Temperature, pressure, flow, and level sensors, Monitoring systems, measurement and control of combustion, Turbine monitoring and control: speed, vibration,shell temperature monitoring, radiation detection instruments, process sensors for nuclear power plants, Data acquisition systems in generating stations.

Activities: Case Study Discussion: Review an example of radiation detection in nuclear plants and its significance for safety.Plant Visit or Virtual Tour: If possible, arrange a site visit to a thermal/nuclear plant, or watch a virtual tour, followed by a reflection discussion.

Substation Instrumentation: Sub-station automation, requirements, control aspects in substations, feeder automation, consumer side automation, reliability, GPIB programmable test instruments - microprocessor / microcontroller based GPIB controllers

Activities: Research Paper Review Activity: “Read one recent paper related to Substation Instrumentation and write a short note about why it is important, and how it relates to what you learned in class.”

Distribution Automation: Concepts of automation in distribution networks, Automation Switching Control, Management Information Systems (MIS), Remote Terminal Units, communication method for data transfer, Consumer Information Service (CIS), Graphical Information Systems (GIS), Automatic Meter Reading (AMR), Remote control load management.

Activities: Diagram Practice: Students draw a basic layout of a distribution automation system and label key components.
Case Study: Review an example of MIS or GIS in a real utility and discuss its benefits.

Energy Management Techniques and Instruments: Need for energy management in power systems, Demand side management (DSM), DSM planning, DSM Techniques, Load management as a DSMstrategy, energy conservation, tariff options for DSM, Energy audit, instruments for energy audit, Energy audit for generation, distribution and utilization systems.

Activities: Demonstration Session: Show actual instruments used for energy audits (power analyzers, thermal cameras, etc.) through a video or live demonstration.
Mini Project: Students create a basic energy audit outline for a site (e.g., campus building), including equipment and data required.

Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%

Assessment Methodology: Quiz (5%), Assignments (10%), Review of Question Papers (IES, GATE, SSC Questions) (20%), Projects (20%), Flipped Class (5%), Internal Examinations (40%).

References:

1. Liptak, B. G. (1973). *Instrumentation in process industries* (Vols. I & II). Chilton Book Co.
2. Sherry, A. (1971). *Modern power station practice* (Vol. 6: Instrumentation, controls and testing). Pergamon Press.
3. Pabla, A. S. (2004). *Electric power distribution*. Tata McGraw Hill.
4. Mahalanabis, A. K., Kothari, D. P., &Ahson, S. I. (1988). *Computer aided power system analysis and control*. Tata McGraw Hill.
5. Murphy, W. R., & McKay, G. (1982). *Energy management*. Butterworths Publications.
6. Turner, W. C. (1982). *Energy management handbook*. John Wiley and Sons.
7. National Programme on Technology Enhanced Learning (NPTEL). (n.d.). *Course on power system protection* [Video lecture]. https://nptel.ac.in/courses/108105088

Description of CO		PO	PSO1	PSO2
CO1:	Understand measurement principles, error analysis, and data acquisition techniques in power systems	PO1(2) PO2(1) PO3(3)	3	2
CO2:	Explain SCADA systems, communication protocols, and control methods in power networks	PO1(2) PO2(1) PO3(3)	3	3
CO3:	Describe advanced instrumentation techniques in thermal and nuclear power plants	PO1(2) PO2(1) PO3(3)	3	2
CO4:	Analyze substation and distribution automation systems for enhanced control and reliability	PO1(3) PO2(2) PO3(3)	3	3
CO5:	Apply energy management strategies and auditing tools for efficient and sustainable power system operation	PO1(3) PO2(2) PO3(3)	3	3

Semester II

PS25201	High Voltage DC Transmission	L	T	P	C
		3	0	0	3

Course Objective:
This course aims to provide a fundamental understanding of HVDC transmission systems and their advantages over AC systems. It focuses on converters, control methods, harmonics, and protection techniques. Students will also explore recent developments in HVDC technology.

Introduction to HVDC Transmission
Introduction to HVDC transmission, Evolution and need for HVDC systems, Comparison between HVAC and HVDC systems - economic, technical and reliability, limitations, Types of HVDC links - monopolar, bipolar and homopolar links, Components of HVDC transmission system

Activities:
- Group Discussion/Debate: "HVDC vs HVAC – Which is better for future grids?" covering technical, economic, and reliability aspects.
- Simulation: Simulate both HVAC and HVDC transmission over a fixed distance using MATLAB/Simulink or PSCAD

Analysis of HVDC Converters
Choice of Converter Configuration, Rectifier and Inverter operation of Graetz circuit without and with overlap, Characteristics of 6 Pulse and 12 Pulse converters, Cases of two 3 phase converters in Y/Y mode and performance. Effect of Source Inductance, modelling, Equivalent circuit of HVDC link.

Activities:
- Group Assignment: Compare two 6 pulse converters connected through Y/Y and Y/Δtransformer. Prepare a report discussing performance differences and harmonic characteristics.
- Simulation: Simulate 6-pulse and 12-pulse Graetz converter circuits using MATLAB/Simulink or PSCAD to observe rectifier and inverter operation in open loop.

Converter & HVDC System Control
Principal of DC Link Control – Converters Control Characteristics – Firing angle control – Constant Current Control, Constant IgnitionAngle control andConstantExtinction Angle control – Effect of source inductance on the system – Startingand stopping of DC link - Power Control –Power Reversal - Higher level Controllers.

Activities:
- Problem Solving & Peer Teaching: In class, students work in pairs or groups to solve realistic control problems (e.g., calculate DC voltage with given firing angle and source inductance). Each group presents their solution and explains the control method used
- Simulation: Simulate firing angle and extinction angle control in a converter using MATLAB/Simulink or PSCAD.

Reactive Power Control and Power Flow Analysis

Reactive Power Control In HVDC: Reactive Power Requirements in steady state, sources of reactive power- Static VAR Compensators, Reactive power control during transients.

Power Flow Analysis in AC/DC Systems: Modelling of DC Links, DC Network, DC Converter, Controller Equations, Solution of DC load flow, P.U. System for DC quantities, solution of AC-DC Power flow.

Activities:

- Technical Seminar: Students prepare posters or give short seminars on topics like “Reactive Power Support in HVDC Systems” or “Challenges in AC-DC Power Flow Integration.”
- Simulation: simulate an HVDC system with reactive power compensation using SVC. Reactive Power Compensation using SVC using MATLAB/Simulink or PSCAD and Observe reactive power balance under steady-state and transient conditions.

Harmonics and Filter

Harmonics in HVDC system - Characteristic and uncharacteristic harmonics - troubles due to harmonics– harmonic filters - active and passive filters - Reactive power control of converters, Protection issues in HVDC, over voltage and over current protection, voltage and current oscillations.

Activities:

- Case Study: Study real-world HVDC systems (e.g., ABB, Siemens projects) and present how they handle harmonic mitigation and overvoltage/overcurrent protection

Multi Terminal HVDC System

Power Flow Analysis in AC/DC Systems: Modelling of DC Links, DC Network, DC Converter, Controller Equations, Solution of DC load flow, P.U. System for DC quantities, solution of AC-DC Power flow.

Activities:

- Simulation: DC power flow analysis using any coding platform.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal
Individual Assignment / Case Study/ Seminar / Mini Project	Written Test	Individual Assignment / Case Study/ Seminar / Mini Project	Written Test		

/ any other experiential Learning		/ any other experiential Learning			Assessment
40	60	40	60	200	

References:

1. Padiyar K R, “HVDC Power Transmission Systems”, 3rd Edition, New Age International Pvt Ltd Publishers, New Delhi, 2017.
2. Kamakshaiah S and Kamaraju V, “HVDC Transmission”, Tata McGraw Hill Publications, New Delhi, 2011.
3. Kimbark E W, Direct Current Transmission, 2nd edition, John Wiley &Sons, New Delhi, 2006
4. Arrillaga, J., ‘High Voltage Direct Current Transmission’, 2nd Edition, Institution of Engineering and Technology, London, 1998.
5. Vijay K. Sood, ‘HVDC and FACTS Controllers’, Kluwer Academic Publishers, New York, 2004.

E- Resources

1. https://nptel.ac.in/courses/108104013
2. https://www.cet.edu.in/noticefiles/229_HVDC_NOTE.pdf

	CO Description	PO Mapping	PSO1	PSO2
CO1	Ability to Describe the need for HVDC transmission and differentiate it from HVAC systems in terms of advantages, limitations, and applications. .	PO1(2) PO2(1) PO3(3)	3	2
CO2	Ability to Explain the operation of HVDC converters and analyze the performance of 6-pulse and 12-pulse converter configurations.	PO1(2) PO2(1) PO3(3)	3	3
CO3	Ability to Apply suitable control strategies for HVDC systems, including firing angle, extinction angle, and power flow control.	PO1(2) PO2(1) PO3(3)	3	2
CO4	Ability to Analyze reactive power requirements and perform AC-DC power flow studies using modeling techniques.	PO1(3) PO2(2) PO3(3)	3	3
CO5	Ability to Identify harmonic problems and protection needs in HVDC systems and describe the structure and control of multi-terminal HVDC systems	PO1(3) PO2(2) PO3(3)	3	3

PS25202	Advanced Power System Protection	L	T	P	C
		3	0	2	4

Course Objective:

- This course aims to equip students with a comprehensive understanding of protection schemes of power systems.
- It focuses on power system relaying scheme for protection of power apparatus using digital techniques.
- Students will also explore PC based algorithm for various protection schemes of power system.

Numerical Protection

Introduction - Block diagram of numerical relay - Sampling theorem - Correlation with a reference wave - Least Error Squared (LES) technique - Digital filtering and numerical over - Current Protection - Numerical transformer differential protection- Numerical distance protection of transmission line.

Activities:

Quiz on Analyse Least Error Squared (LES) technique and its significance.

Digital Protection of Transmission Line

Introduction - Protection scheme of transmission line – Distance relays - Traveling wave relays - Digital protection scheme based upon fundamental signal - Hardware design - Software design - Digital protection of EHV/UHV transmission line based upon traveling wave phenomenon - new relaying scheme using amplitude comparison

Activities:

Group Discussion/Debate: How digital protection schemes adapt to changing system conditions and fault scenarios?

Digital Protection of Synchronous Generator & Transformer

Introduction - Faults in synchronous generator - Protection schemes for Synchronous Generator - Digital protection of Synchronous Generator - Faults in a Transformer - Schemes used for Transformer Protection - Digital Protection of Transformer.

Activities:

Technical seminar: Analyse the principles behind the digital protection of synchronous generators and the algorithms used.

Distance and Overcurrent Relay Setting and Co- Ordination

Directional instantaneous IDMT over current relay - Directional multi-Zone distance relay - Distance relay setting - Co-ordination of distance relays - Co-ordination of over current relays - Computer graphics display - Man-machine interface subsystem - Integrated operation of national power system - Application of computer graphics.

Activities:

Group Discussion/Debate: the benefits of integrated operation of the national power system in relay setting and coordination

PC Applications for Designing Protective Relaying Scheme

Types of faults – Assumptions - Development of algorithm for SC studies - PC based integrated software for SC studies - Transformation to component quantities - SC studies of multiphase systems Ultra-high-speed protective relays for high voltage long transmission line.

Activities:

Case Study: Analyse the steps involved in transforming electrical quantities to component quantities during SC studies for protective relaying

Laboratory Exercise:

1. Study of electromechanical & numerical type IDMT over current relay.
2. Study of directional over current relay.
3. Study of earth fault relay.
4. Study of numerical type differential relay.
5. Study the application of numerical type over current relay for distribution feeder protection and synchrophasor assisted current differential relay for transmission/distribution line protection.
6. Study of transmission line fault detection, classification and location estimation using distance relays by simulating different faults on the WSCC 9-bus test power system through PSCAD/EMTDC software or MATLAB/Simulink.
7. Study of Power Swing and its impact on distance relaying-based transmission line protection scheme through PSCAD/EMTDC software or MATLAB/Simulink

<table>
<tr><td rowspan="2">Assessment Weightage:</td><td>Continuous Assessment: 60%</td><td rowspan="2">End Semester Theory Examination: 40%</td></tr>
<tr><td>1. Activities: 15%
2. Internal Theory Examinations: 30%
3. Internal Laboratory Examinations: 15%</td></tr>
<tr><td colspan="3">Mandated Activities with marks:
Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).</td></tr>
<tr><td colspan="3">Internal Examinations: Two tests</td></tr>
</table>

References:

1. T.S. Madhava Rao, Power system Protection static relay, Tata McGrawHill Publishing Company limited, 2nd Edition, 2004.
2. Badri Ram and D.N. Vishwakarma, Power system Protection and Switchgear, Tata McGraw Hill Publication Company limited, 2nd Edition, 2013.
3. Bhavesh Bhalja, R. P. Maheshwari, N. G. Chothani, Protection and Switchgear, Oxford University Press, 2nd Edition, New Delhi, India, 2018.
4. Oza, B. A., N. C. Nair, R. P. Mehta, et al., Power System Protection & Switchgear, Tata McGraw Hill, New Delhi, 1st Edition, 2011

	CO Description	PO Mapping	PSO1	PSO2
CO1	Ability to Familiarize the underlying principle of digital techniques for power system protection.	PO1(2) PO2(1) PO3(3)	3	2

CO2	Ability to Design the relaying scheme for protection of power apparatus using digital techniques.	PO1(2) PO2(1) PO3(3)	3	2
CO3	Ability to Evaluate and interpret relay coordination. .	PO1(2) PO2(1) PO3(3)	3	3
CO4	Ability to Develop PC based algorithm for short circuit studies	PO1(3) PO2(2) PO3(3)	3	3
CO5	Ability to Compare the performance of modern protection schemes with the conventional schemes	PO1(3) PO2(2) PO3(3)	3	3

*Put weightage for PO based on the CO. If it is not relevant, kindly omit that PO.

PS25203	Power System Restructuring and Pricing	L	T	P	C
		3	0	0	3

Course Objective:
This course aims to provide a fundamental understanding of electricity power business and technical issues in a restructured power system in both Indian and world scenarios. It focuses on power and information flow in a restructured power system.

Introduction to Restructuring of Power Industry
Traditional Power Industry Structure, Motivations for restructuring, Fundamentals of restructured system, Restructuring models, Different industry structures and ownership/ management forms for generation, transmission and distribution. Different market models: Monopoly model, purchasing agency model, wholesale competition model, Retail competition model–Market equilibrium- Market clearing price.

Activities:
- Group Discussion/Debate: "Vertically integrated and Restructured power system" covering technical, economic, and reliability aspects.
- Simulation: Estimation of market clearing price

Operation, Transmission planning and Ancillary Services
Operational and planning activities of a Genco - Electricity Pricing and Forecasting -Price Based Unit Commitment - Security Constrained Unit Commitment - Ancillary Services for Restructuring-Role of transmission planning–TransmissionCapacity–Total transfer capability (TTC) –Available transfer capability (ATC)-Methods to compute ATC.

Activities:
- Group Assignment: Compare different Electricity Price Forecasting Techniques.
- Simulation**:**Estimation of ATC.

Transmission Pricing and Congestion Management
Transmission pricing:power wheeling, transmission open access, cost components in transmission, pricing of power transactions. Congestion management: Inter and Intra zonal Congestion Management–Generation Rescheduling – Locational Marginal Pricing Transmission pricing methods -Postage Stamp-Contract path-MW-mile– MVA mile

Activities:
- Problem Solving & Peer Teaching: In class, students work in pairs or groups to solve realistic congestion managementproblems. Each group presents their solution and explains the methods adopted along with their advantages.
- Simulation: Estimation of LMP using OPF.

Market development and institutional scenario
Comparative study and global experience of historical evolution, regulation, reforms, deregulation models, market trends, operation, critical issues, challenges, future directions of key electricity markets: UK, US (California, New York, PJM, ERCOT, New England), Nordic electricity market.

Activities:

- Case Study: Study real-world market trends and present how they handle issues in real-time deregulated power system
- Simulation: Simulate California market with assumed price bids for various entities

Power Market Development in India

Institutional structure in Indian Power sector, generation, transmission and distribution utilities. SO& LDCs. PFC, REC, ERCs, traders, Power Exchanges and their roles. Availability based tariff, Open access, Industry structure and regulatory framework, market development, RE policies, RPO, Tariff policies. Policy changes, regulatory changes, Critical issues / challenges before the Indian power sector.

Activities:

- Research Paper Review & Presentation: Students review a recent IEEE/Elsevier paper on restructuringand present key findings in class.
- Simulation: Simulate Availability based tariff with various system scenarios.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test		
40	60	40	60	200	

References:

1. Mohammad Shahidehpour, MuwaffaqAlomoush,“Restructured electrical powersy stems: operation, trading and volatility” Marcel Dekker Pub.,2001.
2. Kankar Bhattacharya, Math H.J.Boolen, and JaapE.Daadler, "Operation of restructured power systems”, Kluwer Academic Pub.,2001.
3. Sally Hunt, "Making competition work in electricity”, John Willey and Sons Inc. 2002.
4. Steven Stoft, " Power System Economics: Designing Markets for Electricity”, Wiley-IEEE Press, 2002.

E- Resources

1. https://nptel.ac.in/courses/108101005/
2. https://grid-india.in/en/

	CO Description	PO Mapping	PSO1	PSO2
CO1	Describe the need for power system restructuring and differentiate the different market models.	PO1 (2) PO2 (2) PO3 (3)	2	2
CO2	Explain the operational and planning activities in deregulated power system	PO1 (2) PO2 (2) PO3 (3)	2	3
CO3	Apply suitable methods for estimation of transmission pricing and congestion management.	PO1 (2) PO2 (2) PO3 (3)	2	3
CO4	Analyze the global market models and their reform initiatives.	PO1 (2) PO2 (2) PO3 (3)	2	2
CO5	Analyze the market development in India and identify the Critical issues.	PO1 (3) PO2 (3) PO3 (3)	2	2

PS25204	Smart Power Grid Technologies	L	T	P	C
		3	0	0	3

Course Objective:

- To introduce and discuss the components of the smart grid.
- To discuss and apply the various technologies such as Power Electronics, Advanced Metering Infrastructure, Communication protocols, Distribution Automation and Data Analytics in smart grid.

Smart Grid and its components

Evolution of Electric Grid - Conventional vs smart Grid - Smart grid: opportunities, challenges and benefits - Renewable-based Distributed generations, Energy Storage Technologies - Microgrids - Electric Vehicles -Virtual Power Plant- Flexible Loads- Prosumer.

Activity:

Seminar on Smart Grid Projects in India / Poster Presentation on National Smart Grid Mission 2015-2024.

Power Electronics

Overview of Power Electronics in FACTS, HVDC,Grid connected Renewable Energy Sources and Energy Storage Systems, Power Quality Conditioners for Smart Power Grid, Web based Power Quality monitoring, Power Quality Audit.

Activity:

Case study on Power QualityAuditfor an Industry

Smart meters

Evolution of electricity metering -Conventional meter vs Smart meter- Smart meter: Hardware, Communication Protocols - Advanced Metering Infrastructure (AMI): drivers and benefits, protocols, standards and initiatives.

Activity:

Research Paper discussion on design of smart meters and AMI

Data Analytics and High Performance Computing

Data Analytics: Foundations, Big Data Management, Analytical Models in Utility, Predictive Analysis and Prescriptive Analysis, Operational Analytics.

High Performance Computing:Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Web Service and CLOUD computing,Cyber Security for Smart Grid.

Activities:

Quiz on communication standards for within substation, substation automation, smart meter and between Data Acquisition control and Equipment .

Flipped class room on effects of Data Analytics and Cyber attacks in smart grid.

Distribution System

Distribution Automation

Modern smart substation, Substation automation equipment: SCADA, IED, Bay controller, RTU - Fault location,isolation and restoration in non-automated distribution network.

Distributed Management System (DMS)

Structure and main components (overview) – Customer Information System (CIS) - Automation of DMS – Applications: System monitoring, Integration of Micro Grids and Outage Management System (OMS).

Activity:

Diagram Practice: Students draw a basic layout of a distribution automation system and label key components.

Industrial visit to a Distribution Substation.

Smart grid applications

Fault Location,Isolation and restoration in partially automated and fully automated distribution network of smart grid - Outage Management System (OMS) with/without smart meter- Demand Side Integration (DSI) : DSI Services - Price based DSI and Incentive based DSI - Effect of DSI in system frequency control- Case study on smart gridanalytics.

Activity:

Group discussion on Hardware support on DSI implementation (load control switches, controllable thermostats, lighting control,adjustable speed drives and smart meter with ICT structure)

Mini Project : Demand-side integration- Services Implementation.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

	CO Description	PO Mapping	PSO1	PSO2
CO1	Able to understand the features and architecture of Smart Grid	PO1 (3), PO2 (3), PO3(2)	3	2
CO2	Able to assess the role of automation in transmission and distribution.	PO1 (3), PO2 (3), PO3 (2)	3	3
CO3	Able to understand and analyse the operation of DG and storage technologies.	PO1 (2), PO2 (3), PO3 (2),	3	2
CO4	Able to understand the communication technologies and cyber-security in Smart Grid.	PO1 (3), PO3(3)	3	3
CO5	Able to understand the planning, operation, control and analysis of Smart Electric Grid.	PO1 (3), PO2 (3), PO3 (3)	3	3

Programme Elective Courses

PX25C04	WIND ENERGY CONVERSION SYSTEMS	L	T	P	C
		3	0	0	3

Course Objectives:

- To introduce the various electrical generators and appropriate power electronic controllers employed in wind energy systems.
- To teach the students the steady-state analysis and operation of different existing configurations of electrical systems in wind energy and also the recent developments taking place in this field

Wind turbine system:

Wind statics - Wind energy – energy in the wind – forces developed by blades - turbine power characteristics – classification of wind turbine generator systems - aerodynamics - rotor types –- Aerodynamic models – parts of wind turbines - braking systems – tower - control and monitoring system - design considerations power curve - power speed characteristics – Large scale integration and power quality issues.

Grid Connected Induction Generators (GCIGs):

Principle of operation – steady-state analysis-characteristics of GCIGs- Need for single-phase operation –typical configurations for the single-phase operation of three-phase GCIGs - operation of single-phase and three-phase GCIGs with different power electronic configurations.

Self-Excited Induction Generators (SEIGs) :

Process of self-excitation – steady-state equivalent circuit of SEIG and its analysis - performance equations - widening the operating speed-range of SEIGs by changing the stator winding connection with suitable solid state switching schemes - power electronic controllers used in standalone systems.

Doubly-Fed Induction Generators (DFIGs):

Different operating modes- steady-state equivalent circuit- performance analysis- DFIG for standalone applications- operation of DFIGs with different power electronic configurations for standalone and grid-connected operation.

Permanent Magnet Synchronous Generators (PMSGs):

Operation of PMSGs- steady-state analysis- performance characteristics- operation of PMSGs with different power electronic configurations for standalone and grid-connected operation.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(i). Activities: 10% (ii). Internal Theory Examinations: 30%	

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10),

Internal Examinations: TWO tests

References:

1. Ion Boldea, 'The Electric Generators Handbook- Variable Speed Generators', CRC Press, 2010.
2. M. Godoy Simoes and Felix A. Farret, 'Alternative Energy Systems: Design and Analysis with Induction Generators', CRC Press, 2nd Edition, 2008.
3. *Marcelo Godoy Simões and Felix A. Farret, '**Renewable Energy Systems: Design and Analysis with Induction Generators**', CRC Press, ISBN 0849320313, 2004.*
4. *S.N. Bhadra, D.Kastha and S.Banerje, **'Wind Electrical Systems'**, Oxford University Press,* 2005.
5. Bin Wu, Yongqiang Lang, Navid Zargari, Samir Kouro, 'Power Conversion and Control of Wind Energy Systems', IEEE Press Series on Power Engineering, John Wiley & Sons, 2011.

CO	Description of CO	PO	PSO1	PSO2
CO1	Attain knowledge on the basic concepts of Wind energy conversion system.	PO1 (3) PO2 (3) PO3(2)	3	2
CO2	Analyze the electrical characteristics of various wind-driven electrical generators	PO1 (3) PO2 (3) PO3 (2)	3	3
CO3	Identify and design suitable power electronic converters for wind energy conversion system	PO1 (2) PO2 (3) PO3 (2)	3	2
CO4	Study about the need of Variable speed system and its modelling.	PO1 (3) PO3(3)	3	3
CO5	Learn about Grid integration issues and current practices of wind interconnections with power system.	PO1 (3) PO2 (3) PO3 (3)	3	3

PS25001	Analysis of Electrical Machinery	L	T	P	C
		3	0	0	3

Course Objectives:

- To provide knowledge about the fundamentals of magnetic circuits &analyze the steady state and dynamic state operation of DC machine through mathematical modeling and simulation in digital computer.
- To provide the knowledge of theory of transformation of three phase variables to two phase variables &analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modeling
- To analyze the steady state and dynamic state operation of three-phase synchronous machines using transformation

Principles of Electro Magnetic Energy Conversion

Magnetic circuits, permanent magnet, stored magnetic energy, co-energy- force and torque in singly and doubly excited systems– machine windings and air gap mmf– determination of winding resistances and inductances of machine windings– determination of friction coefficient and moment of inertia of electrical machines.

Activities:

- Simulation**:** Model and simulate the behaviour of transformer windings including vibration and electromagnetic forces using MATLAB/Simulink or PSCAD

DC Machines

Elementary DC machine and analysis of steady state operation- Voltage and torque equations– dynamic characteristics of permanent magnet and shunt DC motors– electrical and mechanical time constants- Time domain block diagrams–transfer function of DC motor-responses– digital computer simulation of permanent magnet and shunt DC machines.

Practical: Simulate the mathematical model of DC Machines using MATLAB/Simulink or PSCAD

Reference Frame Theory

Historical background of Clarke and Park transformations– power invariance and phase transformation and commutator transformation– transformation of variables from stationary to arbitrary reference frame- variables observed from several frames of reference.

- Group Discussion/Debate on "Clarke and Park transformations"- covering technical, economic, and reliability aspects.

Induction Machines

Three phase induction machine, equivalent circuit and analysis of steady state operation free acceleration characteristics– voltage and torque equations in machine variables and arbitrary reference frame variables– analysis of dynamic performance for load torque variations– modelling of multiphase machines- digital computer simulation of three phase induction machines.

Practical: Simulation of mathematical model of Induction machines using MATLAB/Simulink or PSCAD in software environment**.**

Synchronous Machines

Three phase synchronous machine and analysis of steady state operation- voltage and torque equations in machine variables and rotor reference frame variables (Park's equations) – analysis of dynamic performance for load torque variations– digital computer simulation of synchronous machines.

Practical: Simulation of mathematical model of synchronous machines using MATLAB/Simulink or PSCAD.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

References:

1. PaulC.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition, 2010.
2. R Ramanujam,"Modelling and Analysis of Electrical Machines", I.K International Publishing Pvt. Ltd., New Delhi, 2018
3. P S Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers, 2008.
4. A.E, Fitzgerald, CharlesKingsley, Jr, and Stephan D, Umanx, " Electric Machinery", Tata McGraw Hill, 5th Edition,1999
5. Mohammed Fazlur Rahman, Sanjeet K. Dwivedi, Modeling, Simulation and Control of Electrical Drives (Control, Robotics and Sensors), Institution of Engineering and Technology, October 2019, 1st Edition.
6. ShaahinFilizadeh, Electric Machines and Drives: Principles, Control, Modeling, and Simulation, Press, April 2017, 1st Edition. Other Suggested Readings: 1. http://www.nptelvideos.com/course.php?id=493

E- Resources

1. http://www.nptelvideos.com/course.php?id=493

	CO Description	PO Mapping	PSO1	PSO2
CO1	Ability to optimally design magnetics required in power supplies and drive systems.	PO1 (2) PO2 (2) PO3 (3)	3	2
CO2	Ability to acquire and apply knowledge of mathematics of machine dynamics in Electrical engineering.	PO1 (3) PO2 (1) PO3 (3)	3	2
CO3	Ability to model, simulate and analyze the dynamic performance of electrical machines using computational software.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Ability to formulate, design, simulate power supplies and loads for complete electrical machine performance	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Ability to verify the results of the dynamic operation of electrical machine system	PO1 (3) PO2 (3) PO3 (3)	3	3

PS25002	Inverter-Based Renewable Energy Systems	L	T	P	C
		3	0	0	3

Course Objectives:

- To understand inverter technologies for renewable energy integration in modern power systems.
- To analyze control and operational characteristics of inverter-based resources (IBRs).
- To evaluate grid compliance, standards, and protection strategies for inverter-connected systems.
- To design advanced control strategies for grid-supportive and grid-forming inverters.

Fundamentals of Inverter-Based Renewable Energy Systems

Overview of different renewable energy sources (solar, wind, hydro, etc.) and their characteristics. Power electronics interface for renewable energy systems. Types of inverters: Grid-following, grid-forming, and hybrid configurations. Role of inverters in distributed generation and grid modernization. Understanding the need for grid connection and the challenges involved. Cost analysis of renewable energy projects and the impact of incentives.

Activity: Group Discussion:Role of inverters in distributed generation and grid modernization.

Converter Topologies and MPPT Techniques

DC-DC converter design: Boost, buck, interleaved, and SEPIC converters. MPPT techniques: P&O, Incremental Conductance, fuzzy logic-based MPPT.Multilevel inverter topologies: Diode-clamped, flying capacitor, cascaded H-bridge. PWM techniques: Sine PWM, Space Vector PWM, Discontinuous PWM.

Activity: Modeling of grid-connected PV system in MATLAB/Simulink

Control of Grid-Connected Inverters

Grid synchronization techniques-PLL design and implementation- Current control and voltage control modes- Active and reactive power control strategies- Fault ride-through, low voltage ride-through (LVRT), and grid support functionalities.

Activity: Implementation of MPPT in a simulated solar inverter system.

Standalone and Hybrid Inverter Systems

Operation under islanded conditions and load-sharing control-Energy storage integration: BESS, supercapacitors, flywheels-Hybrid systems: PV-Wind-Diesel-Storage with control hierarchy-Microgrid formation, protection, and black start capabilities.

Activity: Case Study on Control strategy design for a hybrid standalone microgrid.

Modeling and Standards

Mathematical modeling of inverter-based sources in power systems- Smart inverters and voltage/frequency regulation- Virtual synchronous machines and inertia emulation- Case studies of large-scale inverter-based renewable plants (e.g., solar farms, wind farms)- Role of inverters in wide-area stability and power quality improvement-Grid codes and interconnection standards: IEEE 1547, IEC 61727, IEC 62116.

Activity: Case Study on Emerging trends: grid-forming inverters, smart inverters, V2G.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

Internal Examinations: Two tests

References:

1. Bimal K. Bose, 'Power Electronics and Motor Drives: Advances and Trends', 1st Edition, Academic Press, Elsevier, 2006.
2. Ned Mohan, Tore M. Undeland, William P. Robbins, 'Power Electronics: Converters, Applications, and Design', 3rd Edition, John Wiley & Sons, 2003.
3. Muhammad H. Rashid, 'Power Electronics: Circuits, Devices and Applications', 4th Edition, Pearson Education, 2013.
4. IEEE Std 1547-2018, 'IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces', IEEE, 2018.
5. IEC 61727:2004, 'Photovoltaic (PV) Systems – Characteristics of the Utility Interface', International Electrotechnical Commission, 2004.
6. IEC 62116:2014, 'Utility-interconnected Photovoltaic Inverters – Test Procedure of Islanding Prevention Measures', International Electrotechnical Commission, 2014.

	CO Description	PO Mapping	PSO1	PSO2
CO1	Ability to demonstrate understanding of inverter technologies used in renewable energy systems and their roles in modern power systems.	PO1 (2) PO2 (2) PO3 (3)	3	2
CO2	Ability to apply advanced control strategies for inverter operation under grid-connected and standalone modes	PO1 (3) PO2 (1) PO3 (3)	3	2
CO3	Ability to analyze and simulate inverter-based systems for dynamic performance and steady-state behavior.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Ability to evaluate the compliance of inverter systems with relevant international standards and grid codes.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Ability to design and assess hybrid energy systems incorporating inverter-based control and energy storage solutions.	PO1 (2) PO2 (2) PO3 (3)	3	3

PX25C02	Electric Vehicles and Power Management	L	T	P	C
		3	0	0	3

Course Objective:

This course aims to equip students with a comprehensive understanding of electric vehicle (EV) architecture, propulsion systems, and energy storage technologies. It focuses on power management strategies that optimize performance, efficiency, and battery life under varying load and driving conditions. Students will also explore smart charging, regenerative braking, grid integration, and the role of power electronics in advancing sustainable transportation systems.

Introduction to Electric Vehicles (EVs)

EV evolution and classification (BEV, HEV, PHEV, FCEV) - EV configurations and architecture -Vehicle dynamics: tractive effort, energy consumption, gradability - Driving cycles: EPA, NEDC, WLTP, and custom profiles

Activities:

Quiz on BEV, HEV, PHEV, FCEV features

Team design activity: Design its architecture (battery, motor, converter, controller layout)

Electric Propulsion and Drive Systems

Types of electric motors used in EVs: PMSM, BLDC, IM, SRM - Motor characteristics and drive selection - Motor control strategies: Field-Oriented Control (FOC), Direct Torque Control (DTC) - Regenerative braking – Torque Vs. Speed Control

Activities:

Group Discussion/Debate: Types of electric motors used in EVs (Pros/cons in EVs ,Torque-speed curve sketch ,strengths/limitations and real-world use of each motor.)

Simulation: Run and observe simulations for **Field-Oriented Control (FOC) vs. Direct Torque Control (DTC)**

Energy Storage Systems and Battery Management

Battery types: Li-ion, NiMH, Lead-acid – comparison and characteristics - Battery modeling and performance parameters - Battery Management Systems (BMS): SoC, SoH, cell balancing - Supercapacitors and hybrid storage systems

Activities:

Technical seminar: Compare Li-ion, NiMH, and Lead-acid batteries based on key parameters

Modelling: Estimate required battery size, discharge rate, and range for an EV

Power Electronics and Energy Conversion

DC-DC converters, inverters, and onboard chargers - Bidirectional power flow and energy recuperation - Charging infrastructure: AC vs DC, wireless charging, V2G systems - Safety, thermal management, and EMI issues

Activities:

Simulation: Simulation or flowchart design during drive and regenerative braking (e.g., motor ↔ battery ↔ grid)

Group Discussion/Debate:Compare AC charging vs DC fast charging (e.g., speed, efficiency, cost, grid impact)

Power Management Strategies and Future Trends

Power flow optimization and energy scheduling in EVs - Smart energy management using AI and predictive algorithms - Integration with smart grids and renewable sources - Trends in EV policy, standardization, and sustainable mobility

Activities:

Case Study:Analyze and optimize power flow between battery, motor, regenerative braking, and auxiliary systems during different drive conditions

Team design activity: Propose an EV charging solution using solar/wind, including storage and grid backup.

Assessment Weightage: Internal Assessment 1 – 15%; Internal Assessment 2 – 15%; Digital Assignments/Simulations (minimum 2) – 10%; Final Assessment – 60%

References:

1. "Advanced Electric Drive Vehicles", Authors: Ali Emadi, MehrdadEhsani, John M. Miller, Publisher:CRC Press, Published Year:2014
2. "Modern Electric Vehicle Technology", Authors: C.C. Chan, K.T. Chau, Publisher: Oxford University Press, Published Year: 2001
3. "Battery Management Systems for Large Lithium-Ion Battery Packs", Author: Philip Weicker, Publisher: SAE International, Published Year:2013
4. "Power Electronics for Electric Vehicles and Energy Storage Systems", Author:Shuai Jiang, Publisher: Springer, Published Year:2022
5. "Electric and Hybrid Vehicles: Technologies, Modeling and Control – A Mechatronics Approach", Authors: Amir Khajepour, M. SaberFallah, AvestaGoodarzi, Publisher:Wiley, Published Year:2014

CO	CO Description	PO	PSO1	PSO2
CO1	Understand the architecture of EV powertrains and identify the role of various subsystems in power and energy flow management.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Analyze battery systems, charging infrastructure, and battery management techniques to ensure safety, efficiency, and longevity of EVs.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Apply power electronics converters and control strategies for energy conversion, bidirectional charging, and regenerative braking in electric vehicles.	PO1 (3) PO2 (2) PO3 (3)	3	2
CO4	Evaluate real-time power management strategies under different driving conditions using performance metrics such as efficiency, thermal stability, and cost-effectiveness.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Design intelligent energy management systems using rule-based, fuzzy logic, and optimization-based algorithms for hybrid and battery electric vehicles.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25003	Energy Auditing and Management	L	T	P	C
		3	0	0	3

Course Objective:

- To study the concepts behind economic analysis and load management
- To emphasize the energy management of various electrical equipment and metering
- To illustrate the concept of energy management technologies

ENERGY SCENARIO

Basics of Energy and its various forms - Conventional and non-conventional sources - Energy policy - Energy conservation act 2001 - Need for energy management- Energy management program - Energy managers and energy auditors - Roles and responsibilities of energy managers - Energy labelling and energy standards.
Activity: Analyzing power factor and energy consumption of selected equipment.

ENERGY COST AND LOAD MANAGEMENT
Important concepts in an economic analysis - Economic models-Time value of money-Utility rate structures- Cost of electricity-Loss evaluation- Load ***management:*** Demand control techniques-Utility monitoring and control system-HVAC and energy management-Economic justification.
Activity: Case study presentation on Bureau of Energy Efficiency (BEE) certified audits.

ENERGY MANAGEMENT
Demand side management (DSM) – DSM planning – DSM techniques – Load management as a DSM strategy – Energy conservation – Tariff options for DSM – Harmonics – Power Factor Improvement and its benefits – Assessment and Estimation of Technical losses in Power System.
Activity: Preparing an energy audit report for a commercial or industrial facility.

ENERGY AUDITING
Definition – Energy audit methodology: audit preparation, execution and reporting – Financial analysis – Sensitivity analysis – Project financing options - Instruments for energy audit – Energy audit for generation, distribution and utilization systems – Economic analysis.
Activity: Design of an energy-efficient lighting system with cost analysis

ENERGY EFFICIENT TECHNOLOGIES
Energy saving opportunities in electric motors - Power factor improvement benefit and techniques Shunt capacitor, Synchronous Condenser and Phase Advancer - Energy conservation in industrial drives, electric furnaces, ovens and boilers - Lighting techniques: Natural, CFL, LED lighting sources and fittings.
Activity: Use of portable instruments (power analyzer, lux meter, IR thermometer) in field assessments.

REFERENCES

1. Barney L. Capehart, Wayne C. Turner, William J. Kennedy, “Guide to Energy Management”, CRC press, Taylor & Francis group, Eighth Edition, 2016.
2. https://prsindia.org/files/bills_acts/bills_parliament/2010/The_Energy_Conservation_Ame ndme nt_Bill_2010.pdf
3. Eastop T.D and Croft D.R, “Energy Efficiency for Engineers and Technologists”, Logman Scientific & Technical, 1990.
4. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.
5. Amit K. Tyagi, “Handbook on Energy Audits and Management”, TERI, 2003.
6. “General Aspects of Energy Management and Energy Audit”, Guide Book for National Certification Examination for Energy Managers and Energy Auditors by Bureau of Energy Efficiency, 2025.
7. “Energy Efficiency in Electrical Utilities”, Guide Book for National Certification Examination for Energy Managers and Energy Auditors by Bureau of Energy Efficiency, 2025.
8. https://www.eeeguide.com/power-factor-improvement.
9. Anil Kumar, Om Prakash, Chauhan Prashant Singh “Energy Management: Conservation and Audits, CRC Press, 2020.
10. Barney L. Capehart, Wayne C. Turner, William J. Kennedy, “Guide to Energy Management”, CRC press, Taylor & Francis group, Eighth Edition, 2016.
11. S.C. Bhatia and SarveshDevraj, “Energy Conservation”, Wood head Publishing India Pvt. Ltd, 2016.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

<table>
<tr><th colspan="2">Internal Assessment I
(100 Marks)</th><th colspan="2">Internal Assessment II
(100 Marks)</th><th rowspan="2">Total Internal Assessment</th><th rowspan="3">The weighted average shall be converted into 40 marks for internal Assessment</th></tr>
<tr><td>Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning</td><td>Written Test</td><td>Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning</td><td>Written Test</td></tr>
<tr><td>40</td><td>60</td><td>40</td><td>60</td><td>200</td></tr>
</table>

	CO Description	PO Mapping	PSO1	PSO2
CO1	Understand the present energy scenario and role of energy managers.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Comprehend the Economic Models for cost and load management.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Configure the Demand side energy management through its control techniques, strategy and planning.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Understand the process of energy auditing.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Implement energy conservation aspects in industries.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25004	ELECTRICAL DISTRIBUTION SYSTEMS	L	T	P	C
		3	0	0	3

Course Objective:

- To explain the principles of design and operation of electric distribution feeders and other components.
- To make the students to understand the distribution system expansion planning and reliability analysis procedures

DISTRIBUTION SYSTEMS

Distribution systems: Types of distribution systems - Section and size of feeders – Primary and secondary distribution – Distribution substations – Effect of working voltage on the size of feeders and distributors – Effect of system voltage on economy – Voltage drop and efficiency of transmission - Qualitative treatment of rural distribution and industrial distribution.

SUBSTATIONS

Types of Substations – busbar arrangements – optimal location – components of a substation – different layouts – single line diagrams – switchgear – substation grounding – step and touch voltages - earthmat calculations as per IEEE 80 – measurement of earth resistance as per IEEE 81 – Lightning protection in substations

CONTROL AND PROTECTION

Voltage control – standards - Power factor improvement – design of Shunt capacitors for voltage drop and loss reduction – Harmonics - analysis and effects – harmonic reduction – static VAR systems

Distribution System protection and grounding – fuses – protection issues in distribution systems - over current protection and coordination – line sectionalizes.

DISTRIBUTED GENERATION AND DISTRIBUTION AUTOMATION

Smart grids – integration of distributed energy resources – advantages and challenges of DER integration – Automation in Distribution systems - Difficulties in implementing distribution Automation in actual practice, Urban/Rural distribution, Energy management, and Artificial Intelligence (AI) techniques applied to distribution automation.

DISTRIBUTION SYSTEM RELIABILITY AND EXPANSION PLANNING

Distribution system reliability analysis – reliability concepts – Markov model –reliability performance evaluation - Distribution system expansion and planning – load characteristics – load forecasting – design concepts

Activities:

1. Design a 11 kV distribution system choosing a small study system and prepare the one-line diagram of the system
2. Design an earth mat for a substation as per IEEE80 standard
3. Measurement of earth resistance (field testing) as per IEEE81
4. Design a coordinated over current protection scheme for a radial distribution network
5. Verification of impacts of power factor improvement on voltage regulation, losses and efficiency of a distribution system –A case study
6. Effect of integration of Distributed Energy Resources on distribution network on regulation and fault levels – A case study using suitable software
7. Measurement of harmonics and analysis of underlying factors in a system (field testing)

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment/ Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment/ Case Study/ Seminar/ MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

References:

- A.S. Pabla, "Electric Power Distribution", Tata McGraw Hill Publishing Co. Ltd., New Delhi, Sixth Edition, 2017.
- M.K. Khedkar, G.M. Dhole, "A Text Book of Electrical Power Distribution Automation", University Science Press, New Delhi, First Edition, 2010
- Turan Gonen, "Electric Power Distribution", CRC Press. Third Edition, 2014.
- V. Kamaraju, "Electrical Power Distribution Systems", Tata McGraw Hill Books Company, Sixth Edition, 2009.
- James Momoh, "Electric Power Distribution, Automation, Protection & Control", CRC Press. First Edition, 2007

	CO Description	PO Mapping	PSO1	PSO2
CO1	Explain the structure, components, and operation of electrical distribution systems.	-	-	-
CO2	Analyze voltage regulation and load flow in radial and loop distribution systems.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Design solutions for reactive power compensation and voltage profile enhancement.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Apply automation, communication, and protection techniques in distribution networks	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Evaluate the impact of distributed generation and reliability indices in planning.	PO1 (2) PO2 (2) PO3 (3)	3	3

<table>
<tr><td rowspan="2">PS25005</td><td rowspan="2">IoT for Smart Energy Management Systems</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td colspan="6">Course Objective: The objectives of the course are,
• To provide fundamental knowledge of the Internet of Things, Protocols, smart measuring devices, security threats and applications in real-time monitoring, control, and optimization.
• To familiarize students with IoT technologies used in smart grids, renewable integration, and demand-side energy management.</td></tr>
<tr><td colspan="6">Fundamentals of IoT
Internet of Things - Physical Design- Logical Design- IoT Enabling Technologies - IoT Levels& Deployment Templates - Domain Specific IoTs - IoT Platforms Design Methodology - IoT reference architecture.</td></tr>
<tr><td colspan="6">Activity1 : Quiz on IoT basics and Industrial visit to IoT implemented industries.</td></tr>
<tr><td colspan="6">Communication Technologies and IoT Protocols
Protocol Standardization for IoT - IEEE 802.15.4, Zigbee, LoRa, NB-IoT, Network design for IoT-enabled smart grids, Cloud platforms and edge computing in IoT.</td></tr>
<tr><td colspan="6">Activity 2:Hands-on session on interconnection of 3 or more Raspberry Pis/Arduinos implementing any one protocol.</td></tr>
<tr><td colspan="6">Smart Measuring Devices
Phasor Measurement Unit (PMU), Limitations of RTU, GPS Time Synchronization, Location &Placement, Features - Wide Area Monitoring Systems (WAMS) - Sub-station AutomationSystems (SAS).
Distribution Automation Systems (DAS)- Architecture of Smart Metering Systems, Integration of IoT with SCADA and AMI, Energy usage monitoring and load profiling, Real-time data acquisition and analytics, Use of Raspberry Pi/Arduino for data acquisition.</td></tr>
<tr><td colspan="6">Activity 3:Mini-Project on data acquisition of Raspberry Pis and Arduinos and transmitting to another Raspberry Pis and Arduinos which follows the protocol as in activity 2.</td></tr>
<tr><td colspan="6">IoT applications in energy management
Smart homes and buildings:Smart Lighting, Air Conditioning, and Temperature Controls, Energy efficiency through IoT, Green Energy Management: Integration and monitoring of wind/solar/hybrid systems with IoT-based controls.</td></tr>
<tr><td colspan="6">Activity 4:Flipped Class Room on IoT based grid integration of solar, wind and EV.</td></tr>
<tr><td colspan="6">IoT applications in Power Systems
Load forecasting using IoT and AI, Demand Response and IoT, Smart Storage systems- Smart inverter- Interoperability and standards (IEEE, IEC), Microgrids and IoT coordination in connected power plants.</td></tr>
<tr><td colspan="6">Activity 5:Mini-Project on switching on/off sources and loads of a Micro-grid usingRaspberPis/Arduinos.</td></tr>
<tr><td colspan="6">Security, Privacy, and Regulatory Aspects
Security challenges in IoT for energy systems, Cryptography and authentication protocols, Cybersecurity in SCADA and grid systems, Data privacy concerns and mitigation, Regulatory policies.</td></tr>
<tr><td colspan="6">Activity 6 :Seminar/Poster Presentation on cybersecurity threat on power systems</td></tr>
</table>

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

Text Books:

1. Hanes David, Salgueiro Gonzalo, Grossetete Patrick , Barton Rob, Henry Jerome, 'IoT Fundamentals', Pearson India, 2017.
2. Janaka B. Ekanayake, Nick Jenkins, Kithsiri M. Liyanage, Jianzhong Wu, Akihiko Yokoyama, 'Smart Grid: Technology and Applications', Wiley, 2012.
3. Fei Hu (Editor), 'Security andPrivacyinInternet of Things: Models, Algorithms, andImplementations', CRC Press, 2016.
4. Eric D. Knapp, Raj Samani, 'Applied Cyber Security and the Smart Grid: Implementing Security Controls into the Modern Power Infrastructure', Syngress; 1st edition, 2013.
5. Qasim Alazzawi, M., Sánchez-Aarnoutse, J.-C., Martínez-Sala, A.S. and Cano, M.-D. (2025), 'Green IoT: Energy Efficiency, Renewable Integration, and Security Implications'. IET Netw, 14: e70003. https://doi.org/10.1049/ntw2.70003
6. https://onlinecourses.nptel.ac.in/noc21_ee85/preview

	CO Description	PO Mapping	PSO1	PSO2
CO1	Acquire the fundamentals of IoT and Analyze IoT communication protocols.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Identify the role of IoT in Power systems Measurements.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Apply and Analyze IoT for smart Energy Management Systems.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Apply and Analyze IoT for Power Systems.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Analyze security challenges and cyberattack prevention for smart grid.	PO1 (2) PO2 (2) PO3 (3)	3	3

PX25C03	POWER QUALITY	L	T	P	C
		3	0	0	3

Course Objective:

- Understand the various power quality phenomenon, their origin, impact and monitoring methods.
- Equip the necessary skills to handle power quality problems.

ELECTRIC POWER QUALITY PHENOMENA:

Introduction to power quality, IEEE and IEC - EMC standards, overview, sources and impact of power quality disturbances – RMS voltage variations, interruptions, voltage fluctuation, transients, waveform distortion and power frequency variations.

HARMONICS:

Harmonic sources, measurement of harmonic distortion, current and voltage limits of distortion, harmonic analysis using Fourier transform, effects of harmonic distortion and harmonic filters

POWER DEFINITIONS:

Instantaneous power and other power definitions for single-phase system under sinusoidal and non-sinusoidal conditions, three-phase balanced and unbalanced systems under sinusoidal and non-sinusoidal conditions

POWER QUALITY MONITORING:

importance and introduction to power quality monitoring, overview of power quality disturbance classification, signal processing of disturbances, power quality indices estimation and case studies.

CUSTOM POWER DEVICES:

Introduction to shunt and series compensators, DSTATCOM, Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC) – case studies.

Weightage	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(i). Activities: 10% (II) Internal Theory Examinations: 30%	

Mandated Activities with marks:

Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25)

Internal Examinations: TWO tests

Reference Books:

1. Dugan R. C., Mc Granaghan M. F. Surya Santoso, and Beaty H. W., 'Electrical Power System Quality', McGraw-Hill 2003.

2. Bollen, M. H. J., 'Understanding Power Quality Problems; Voltage sags and interruptions', IEEE Press, New York, 2000.

3. Mishra, Mahesh Kumar, 'Power Quality in Power Distribution Systems Concepts and Applications', CRC Press, Taylor & Francis, New York, 2024.

4. Ghosh, Arindam, and Gerard Ledwich, 'Power quality enhancement using custom power devices' Springer Science & Business Media, 2012.

5. Arrillaga, J., Watson, N. R., Chen, S., 'Power System Quality Assessment', Wiley, New York, 2011.

CO	Description of CO	PO	PSO1	PSO2
CO1	Understand different types of power quality problems with their sources of generation.	PO1(2) PO2(2)	3	2
CO2	Interpret and analyse the results of power quality monitoring equipment.	PO1(2) PO2(2) PO4(1)	3	3
CO3	Develop different methodologies for detection and classification of power quality problems.	PO1(2) PO3(2) PO5(2)	3	3
CO4	Interpret and analyse the results of power quality monitoring equipment.	PO1(2) PO2(2) PO4(1)	3	3

PS25006	System Theory	L	T	P	C
		3	0	0	3

Course Objectives:

This course aims to

1. Understand fundamentals of linear and nonlinear system behavior.
2. Formulate and analyze system models using state-space and transfer function approaches.
3. Apply system-theoretic tools for stability, controllability, and observability.
4. Relate system-theoretic principles to real-world power systems modeling and control.

Introduction to System Theory

Continuous and discrete-time systems- Classification: linear vs nonlinear, time-invariant vs time-varying- System modeling: physical systems, block diagrams, signal flow graphs.

Activity: Modeling and simulation of dynamic systems using MATLAB/Simulink (state-space and transfer function models).

State-Space Analysis

State variables and state-space representation- Solution of state equations- Eigenvalues, eigenvectors, diagonalization- Controllability and observability (Kalman's tests)

Activity: Simulation of power system stability using linearized models

Transfer Function and Frequency Response

Transfer function from state-space- BIBO stability vs Lyapunov stability- Frequency response, Bode plots, Nyquist criteria

Activity: Comparative analysis of BIBO and Lyapunov stability on nonlinear dynamic models.

Nonlinear System Theory

Phase-plane analysis, limit cycles- Describing function method- Lyapunov's direct method for nonlinear systems- Stability analysis of non-linear models in power systems

Activity: Stability analysis of linear and nonlinear systems using root locus, Nyquist, and Lyapunov methods.

Applications to Power Systems

Modeling of synchronous machines, AVR, turbine governors- Small-signal stability analysis- Introduction to system identification techniques- Use of MATLAB/Simulink for dynamic system modelling.

Activity: Case study: Modeling and simulation of a synchronous machine with excitation system.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

References:

1. Katsuhiko Ogata, 'Modern Control Engineering', 5th Edition, Pearson Education, 2010. - A comprehensive text covering both classical and modern control theories including system modeling, stability analysis, and design techniques.
2. I.J. Nagrath and M. Gopal, 'Control Systems Engineering', New Age International, 2007. - This book provides foundational concepts and practical approaches to control system analysis and design.
3. P. Kundur, 'Power System Stability and Control', McGraw-Hill, 1994. - Industry-standard reference for modeling and stability analysis of power system components including machines and controllers.
4. João P. Hespanha, 'Linear Systems Theory', Princeton University Press, 2009. - A mathematically rigorous approach to linear systems and control theory, useful for advanced state-space analysis.
5. Thomas Kailath, 'Linear Systems', Prentice-Hall, 1980. - A foundational text focused on linear system theory with emphasis on state-space methods, controllability, and observability.

	CO Description	**PO Mapping**	**PSO1**	**PSO2**
CO1	Formulate mathematical models for power and control systems using system theory principles.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Analyze system behavior using time-domain and frequency-domain tools.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Assess system stability through Lyapunov, Routh-Hurwitz, and root-locus methods.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Evaluate controllability, observability, and design state feedback controllers.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Apply system theory to dynamic analysis of synchronous machines and power network components.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25007	Advanced Power System Dynamics	L	T	P	C
		3	0	0	3

Course Objective:
To perform transient stability analysis using unified algorithm, impart knowledge on sub-synchronous resonance and oscillations, analyse voltage stability problem in power system and familiarize the methods of transient stability enhancement.

SUBSYSNCHRONOUS RESONANCE (SSR) AND OSCILLATIONS
Sub sysnchronous Resonance (SSR) – Types of SSR – Characteristics of series – Compensated transmission systems –Modelling of turbine-generator-transmission network- Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Methods of analyzing SSR – Numerical examples illustrating instability of sub synchronous oscillations –time-domain simulation of sub synchronous resonance – EMTP with detailed synchronous machine model- Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters.
Activities: To investigate the phenomenon of SSR in power systems, understand its causes and effects, and explore mitigation strategies using simulation and literature analysis.

TRANSMISSION, GENERATION AND LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS
Review of transmission aspects – Generation Aspects: Review of synchronous machine theory – Voltage and frequency controllers – Limiting devices affecting voltage stability – Voltage reactive power characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load Aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.
Activities: Analyse the impact of transmission limits, generator reactive support, and load characteristics on voltage stability through simulation and case-based discussion.

SMALL SIGNAL STABILITY ANALYSIS AND ENHANCEMENT
Multi machine small signal stability analysis – Effects of Excitation System – Power System Stabilizer: Block diagram with AVR and PSS, Illustration of principle of PSS application with numerical example, Block diagram of PSS with description, system state matrix including PSS, analysis of stability with numerical example. Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix with classical model and variable voltage behind transient reactant model of synchronous machines, illustration of stability analysis using a numerical example. Principle behind small-signal stability improvement methods: delta-omega and delta P-omega stabilizers.
Activities: Perform small signal stability analysis of a SMIB system using eigenvalue analysis and propose enhancement using Power System Stabilizer (PSS).

UNIFIED ALGORITHM FOR DYNAMIC ANALYSIS OF POWERSYSTEMS
Need for unified algorithm- numerical integration algorithmic steps-truncation error- variable step size – handling the discontinuities- numerical stability- application of the algorithm for

transient. Mid-term and long-term stability simulations.

Activities: Implement a unified algorithm for dynamic analysis of power systems using numerical integration to simulate generator and network interactions.

INSTABILITY MECHANISM AND COUNTER MEASURES

Types of Counter measures – Classification of Instability Mechanisms – Examples of Short term Voltage Instability- Counter measures to Short – term Instability – Case studies of Long Term voltage Instability – Corrective Actions against Long-term Instability.

Activities: Identify power system instability mechanisms (voltage, angle, frequency) through case studies and propose appropriate countermeasures such as FACTS devices, load shedding, or controller tuning.

References

1. R.Ramanujam," Power System Dynamics Analysis and Simulation, PHI Learning Private Limited, New Delhi,2009
2. T.V. Cutsem and C.Vournas, "Voltage Stability of Electric Power Systems", Kluwer publishers,1998.
3. P. Kundur, Power System Stability and Control, McGraw-Hill,1993.
4. H.W. Dommel and N.Sato, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS-91, pp, 1643-1650, July/August1972.
5. Roderick J.Frowd and J. C. Giri, "Transient stability and Long term dynamics unified", IEEE Trans., Vol 101, No. 10, October1982.
6. M.Stubbe, A.Bihain,J.Deuse, J.C.Baader, "A New Unified software program for the study of the dynamic behaviour of electrical power system," IEEE Transaction, Power Systems, Vol.4.No.1,Feb:1989,Pg.129 to 138.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

	CO Description	PO Mapping	PSO1	PSO2
CO1	Understand the concepts behind sub-synchronous resonance and detect the SSR by suitable modeling.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Analyze the effect of generation and transmission and load dynamics on voltage stability.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Analyze the effect of load dynamics on power system voltage stability.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Analyze the short-term and long-term stability of the power system using unified stability algorithm.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Study and analyze the various instability mechanisms of voltage stability	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25008	POWER SYSTEM PLANNING AND RELIABILITY	L	T	P	C
		3	0	0	3

Course Objectives:

The course aims to

- To equip students with the analytical and planning tools required to forecast power system demand.
- To optimize expansion strategies, and evaluate system reliability under various operating conditions.
- Gain knowledge of power system reliability assessment techniques.
- Develop the ability to evaluate and improve system reliability and security.

Introduction and Load Forecasting

Need for power system planning, power system development stages, data requirement, Load forecasting techniques: time trend, curve fitting, econometric models, end-use method.

Practicals: Load forecasting using time-series models in MATLAB/Python Load growth analysis using real utility data

Generation Expansion Planning

Generation system reliability analysis, generation capacity planning, energy forecasting, screening curve analysis, optimal mix of generation, probabilistic vs deterministic methods.

Practicals: Generation expansion simulation using probabilistic methods Software-based case study on optimal capacity addition

Transmission Expansion Planning

Transmission planning criteria, methodologies: deterministic and probabilistic, network analysis, wheeling, and congestion studies, economic transmission planning, planning under deregulated environment.

Practicals: Power flow simulation using PSS/E or DIgSILENT **Reliability analysis of transmission networks**

Distribution System Planning

Distribution system load characteristics, planning objectives and constraints, substation and feeder planning, distributed generation impact, reliability indices: SAIFI, SAIDI, CAIDI, etc.

Practicals: Feeder reconfiguration and load flow study Reliability index computation for a sample distribution system

Power System Reliability

System adequacy and security, reliability modeling of generation and transmission systems, Markov processes, reliability indices for interconnected systems, reliability cost evaluation.

Practicals: Reliability block diagrams and Monte Carlo simulations Case study: Reliability evaluation of IEEE 6-bus system.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar /MiniProject / anyother experiential Learning	Written Test		
40	60	40	60	200	

References:

- Roy Billinton and Ronald N. Allan, Power System Reliability Evaluation, 2nd Edition, Springer, 1996.
- TuranGonen, Electric Power Distribution System Engineering, 3rd Edition, CRC Press, 2014.
- J. Wood and B. Wollenberg, Power Generation, Operation and Control, 3rd Edition, Wiley, 2014.
- Mehta V.K. and Mehta R., Principles of Power System, S. Chand Publishing, 2018.
- S.S. Rao, Engineering Optimization, 4th Edition, New Age International, 2009.

E-resources:

1. https://docs.nrel.gov/docs/fy24osti/85880.pdfhttps://www.sciencedirect.com/science/article/abs/pii/S1364032118306269
2. https://www.dgardiner.com/wp-content/uploads/2024/03/CAPS-Transmission-Handbook-Volume-4.pdf

	CO Description	PO Mapping	PSO1	PSO2
CO1	Understand the need for power system planning, and apply basic forecasting techniques to estimate future power system demand.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Apply deterministic and probabilistic methods to plan generation capacity expansion considering reliability and economics.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Analyze and plan transmission system expansion using appropriate technical and economic criteria under conventional and deregulated environments.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Evaluate and design distribution system planning	PO1 (3)	3	3

	CO Description	PO Mapping	PSO1	PSO2
	strategies considering load characteristics, reliability, and distributed generation.	PO2 (2) PO3 (3)		
CO5	Apply reliability models and quantitative techniques to assess and improve system adequacy and security	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25C01	Distributed Generation and Micro-Grids	L	T	P	C
		3	0	0	3

Course Objectives:

This course aims to

- Understand the planning and operational issues related to Distributed Generation
- Understand various configurations of Micro-grids
- Analyse the various operating conditions of Micro-grids with and without DGs
- Evaluate the technical, economic, and regulatory challenges of DG and microgrids.
- Foster skills for planning and designing microgrids in urban and remote settings.

INTRODUCTION

Need for Distributed generation, renewable sources in distributed generation, current scenario in Distributed Generation, Planning of DGs – Siting and sizing of DGs – optimal placement of DG sources in distribution systems, Load Flow for Distribution Systems with and without DGs.

Activity: Analysis of interconnection issues such as voltage rise and harmonics in distribution systems.

DISTRIBUTED ENERGY SOURCES

Grid integration of DGs – Different types of interfaces - Inverter based DGs and rotating machine-based interfaces - Aggregation of multiple DG units. Energy storage elements: Batteries, ultra-capacitors, flywheels. Technical impacts of DGs – Transmission systems, Distribution systems.

Activity: Analysis of interconnection issues such as voltage rise and harmonics in distribution systems.

DG PLANNING & PROTECTION

De-regulation – Impact ofDGs uponprotective relaying– Impact of DGs upontransientand dynamic stability of existing distribution systems. Transients in micro-grids - Protection of micro-grids – Reliability of DG based systems – Steady-state and Dynamic analysis.

Activity: Case study: economic analysis and feasibility of a microgrid for a remote village.

MICRO GRIDS

Introduction to micro-grids – Types of micro-grids – autonomous and non-autonomous grids. Sizing of micro-grids- modelling & analysis- Micro-grids with multiple DGs – Micro- grids with power electronic interfacing units.

Activity: Hands-on lab: Interfacing DG units with grid using dSPACE or similar platform (if available).

CONTROL TECHNIQUES

Case studies - Economic and control aspects of DGs –Market facts, issues and challenges - Limitations of DGs. Voltage control techniques, Reactive power control, Harmonics, Power quality issues.

Activity: Group project: Proposal for a smart microgrid implementation in a real-world scenario (e.g., hospital, university, EV charging hub).

Assessment Weightage:	Continuous Assessment: 40% (i). Activities: 10% (ii). Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks:
Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).

Internal Examinations: TWO tests

References:

1. H. Lee Willis, Walter G. Scott ,'Distributed Power Generation – Planning and Evaluation', Marcel Decker Press, 2000.
2. M.GodoySimoes, Felix A.Farret, 'Renewable Energy Systems – Design and Analysis with Induction Generators', CRC press.
3. Robert Lasseter, Paolo Piagi, ' Micro-grid: A Conceptual Solution', PESC 2004, June 2004.
4. F. Katiraei, M.R. Iravani, 'Transients of a Micro-Grid System with Multiple Distributed Energy Resources', International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June 19-23, 2005.
5. Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson 'Facility Microgrids', Subcontract report, May 2005,

	CO Description	PO Mapping	PSO1	PSO2
CO1	Understand the current scenario and need for the implementation of DGs.	PO1 (2) PO2 (2) PO3 (3)	3	3
CO2	Investigate the types of interfaces and control schemes for the grid integration of DGs	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Evaluate the technical and economic impacts of DGs	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Understand different configurations of micro-grid and its modelling.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Evaluate the economic viability and regulatory implications of DG and microgrids.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25009	Power System Transients	L	T	P	C
		3	0	0	3

Course Objective:

- This course is intended to discuss the transients initiated in an integrated power system along with their causes & effects.
- It helps in identifying basic design criteria for power system components to survive such transients. It also introduces EMTP for the computation of transients.

Introduction to Power System Transients

Sources and types of transients- Traveling waves on transmission lines- Reflection and refraction of waves- Basic equations and wave propagation concepts.

Activity: Modeling of traveling wave propagation in transmission lines using MATLAB.

Switching Transients

Transients due to switching of inductive and capacitive loads- Circuit breaker operation and restriking phenomena-Load rejection and energization of lines and transformers Mitigation of switching transients

Activity: Analysis of switching transients in capacitor banks and transformer energization.

Lightning Transients

Lightning discharge mechanism- Modeling of lightning strokes- Protection of transmission lines and substations- Lightning arresters and surge protection devices.

Activity: Simulation of lightning stroke impact on transmission systems in PSCAD/EMTP.

Fault and Temporary Overvoltages

Short-circuit transients and fault initiation- Temporary overvoltages due to resonance and ferroresonance- Neutral grounding and its impact on transients- Use of protection schemes to handle fault transients.

Activity:Group Discussion: Analysis of fault-induced transients in a 33 kV feeder.

Simulation and Mitigation Techniques

Numerical methods for solving transient equations- EMTP (Electromagnetic Transients Program) and PSCAD basics- Insulation coordination and protective device modeling- Case studies of transient phenomena and mitigation strategies.

Activity:Group Discussion: Mitigation of switching and lightning transients in a substation.

Assessment Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	(iii).Activities: 10% (iv). Internal Theory Examinations: 30%	

Mandated Activities with marks:
Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).

Internal Examinations: TWO tests

References:

1. Allen Greenwood, 'Electrical Transients in Power Systems', Wiley-Interscience, 2nd Edition, 1991.
2. C.S. Indulkar and D.P. Kothari, 'Power System Transients: A Statistical Approach', PHI Learning.
3. J. Arrillaga and N.R. Watson, 'Power System Electromagnetic Transients Simulation', IET, 2002.
4. Hileman, 'Insulation Coordination for Power Systems', CRC Press.
5. IEEE Std C62 series and technical papers from IEEE Transactions on Power Delivery and PES General Meetings.

	CO Description	PO Mapping	PSO1	PSO2
CO1	Explain the origins and classifications of power system transients	-	-	-
CO2	Analyze transient wave propagation and circuit behavior during switching and lightning events.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Apply numerical methods and tools to simulate transient responses.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Design insulation and protection systems against transients	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Conduct case studies and evaluate mitigation strategies for transient overvoltages	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25010	GRAPH THEORY APPLICATIONS TO POWER SYSTEMS	L	T	P	C
		3	0	0	3

Course Objective:

The objective of this course is to equip students with fundamental concepts and techniques of graph theory and apply them to analyze, model, and solve complex problems in power system networks effectively.

FUNDAMENTALS OF GRAPH THEORY

Overview of graph theory and its significance in network analysis, Basic network and graph terminologies – Types of graphs: Simple graphs, Multi-graphs, Regular graphs, Concepts of Sub-graphs, Isomorphism and Isomorphic graphs, Special graphs: Eulerian and Hamiltonian graphs, Introduction to directed and undirected graphs and their characteristics.

Activity: Concept Mapping - To draw and label different types of graphs (simple, multi, regular, Eulerian, Hamiltonian, etc.) with real-world power system examples; Quiz on graph terminology and identification of graph types.

TREES AND CUT-SETS

Introduction to trees and their properties – Distance, centers, and various classifications, Rooted trees – Enumeration of trees – Labelled and unlabelled trees, spanning trees: Definitions and algorithms for minimum and maximum spanning trees, Fundamental circuits – Cut-sets and their properties, Relationship between fundamental circuits and cut-sets – Connectivity and separability – Associated theorems.

Activity: Hands-on Exercise - Identify and construct spanning trees from given power system network graphs using Kruskal's and Prim's algorithms; Group Task - Solve connectivity and separability problems using cut-sets and circuits.

NETWORK FLOWS AND PLANAR GRAPHS

Concept of network flows in graph theory – Identification and representation of planar graphs, Dual graphs – Geometric and combinatorial duals, Introduction to directed graphs (digraphs) – Properties of digraphs – Eulerian digraphs, Relevant theorems supporting network flow analysis.

Activity: Simulation Task - Create and analyze planar representations of power system networks and derive dual graphs, Problem Solving - Calculate maximum network flow using given digraphs and Euler paths.

MATRIX REPRESENTATIONS AND GRAPH COLORING

Matrix representation of graphs – Adjacency matrix, Primitive matrices, Incidence matrix, Cut-set matrix, and Path matrix – Properties and applications, Graph coloring – Chromatic polynomials and chromatic partitioning, Concepts of matching and covering in graphs – Important theorems and their implications in network structures.

Activity: Worksheet - Fill in adjacency, incidence, and cut-set matrices from small power system diagrams, Programming Lab - Implement graph coloring and matching algorithms using Python or MATLAB.

POWER SYSTEM APPLICATIONS

Graph algorithms relevant to power systems - Optimal pathfinding algorithms, Depth-First

Search (DFS), Breadth-First Search (BFS), Dijkstra's algorithm, Bellman-Ford algorithm, Ford-Fulkerson algorithm for maximum flow, Programming techniques and practices for solving power system problems using graph-based methods.

Activity: Mini Project - Develop a program using Dijkstra's or Bellman-Ford algorithm to find the optimal path in a power distribution network, Case Study - Analyze a real power system fault scenario using graph traversal or flow algorithms.

References

1. Narsingh Deo, "Graph Theory with Application to Engineering and Computer Science", Prentice Hall of India Pvt. Ltd, 2003.
2. Diestel, R, "Graph Theory", Springer, 3rd Edition, 2006.
3. Bondy, J. A. and Murty, U.S.R., "Graph Theory with Applications", North Holland Publication,2008.
4. West, D. B., "Introduction to Graph Theory", Pearson Education, 2011.
5. John Clark, Derek Allan Holton, "A First Look at Graph Theory", World Scientific Publishing Company, 1991. 6 Clark J. and Holton D.A, "A First Look at Graph Theory", Allied Publishers, 1995.

Assessment Weightage:	Continuous Assessment: 40% (v). Activities: 10% (vi). Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks:
Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).

Internal Examinations: TWO tests

	CO Description	**PO Mapping**	**PSO1**	**PSO2**
CO1	Describe key graph theory concepts and their relevance to power systems	-	-	-
CO2	Apply tree and cut-set properties to analyze network connectivity.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Use planar and dual graphs to model power system networks.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Represent networks using graph matrices for computational analysis	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Implement graph algorithms to solve power system problems efficiently.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25011	Design of Solar PV Systems	L	T	P	C
		3	0	0	3

Course Objective:
This course aims to provide a fundamental understanding of Photo Voltaic Solar systems and their advantages. It focuses on history, Future, Equipment's, Design, Installation and operation techniques. Students will also explore recent developments in PV technology.

Introduction to Solar PV
Introduction to Solar, CSP vs PV, Global and Indian Status – Types of PV Solar Plants – Grid Connected – Standalone – DC Microgrids – Economic evaluation – Capital and Running Cost of PV vs other sources, Cost of Energy – Life of Solar Plants
Activities:
- Group Discussion/Debate: "PV vs CSP – Which is better for future grids?" covering technical, economic, and reliability aspects.
- Simulation: Simulate both Grid Connected and Standalone PV System using PVSYST

Solar Plant Equipment's and Configuration – DC Side
Solar Panel, Manufacturing of PV Module - Types of PV Module – Testing of PV Module - Working Principle of PV Cell – Characteristics of PV Cell – Manufacturers of PV Panel – String Combiner Box – DC Cables – Tracking – Fixed Tilt – Seasonal Tilt – Single Axis Tracking vs Dual Axis Tracking
Activities:
- Group Assignment: Compare Fixed Tilt vs Seasonal Tilt from cost and Energy perspective
- Simulation**:** Perform Simulation for 5 MW solar plant with Single Axis Tracker and compare the energy yield with fixed tilt.

Solar Plant Equipment's and Configuration – AC Side
Solar Inverter – Central Inverter and String Inverter – Night Q Mode of Solar Inverters – Inverter Duty Transformer – Two Winding Transformer vs Multi Winding Transformer - MV Voltage Selection – MV Switchgear – RMU – MV Cables – Power Transformers - Power evacuation
Activities:
- Group Assignment: Compare Central inverter vs String inverter for energy and cost perspective
- Group Assignment: Compare Two winding transformer vs Multi Winding Transformer arrangement for reliability and cost perspective

Reactive Power Control and Power System Studies
Reactive Power Control – Transformer OLTC Selection – Evaluation of Losses - Reactive Power Requirements in steady state - Short Circuit Studies – Protection for Solar Plants – Harmonic Analysis – Arc flash studies
Activities:
- Technical Seminar: Power System studies for Solar plant and role power system simulation softwares
- Simulation: Perform power system studies for solar plant design using ETAP / PSS/e / DigsilentPowerfactory.

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test		
40	60	40	60	200	

E- Resources

1. Solar Plant Design using PVSYST https://www.youtube.com/watch?app=desktop&v=LMdNHV-NXQ8
2. Installed Capacity Report - Central Electricity Authority - https://cea.nic.in/installed-capacity-report/?lang=en

	CO Description	PO Mapping	PSO1	PSO2
CO1	Explain solar radiation principles and photovoltaic conversion mechanisms.	-	-	-
CO2	Analyze PV cell/module performance under varying environmental conditions.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Design efficient and reliable stand-alone and grid-connected solar PV systems.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Simulate and evaluate PV system performance using industry tools.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Perform economic feasibility and sustainability analysis for PV system deployment.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25012	BIG DATA ANALYTICS IN POWER SYSTEMS	L	T	P	C
		3	0	0	3

Course Objective:
The course aims to equip students with knowledge and skills to apply big data analytics, machine learning, and advanced computational tools for efficient monitoring, control, and decision-making in modern power systems.

BIG DATA IN POWER SYSTEMS
Introduction to big data concepts in power systems – Holistic data management approaches – Challenges in data security and privacy for utilities – Cognitive computing applications – Frameworks and architectures for big data integration in power sector.
Activity: Case Study Presentation on Big Data Integration in Power Utilities.

DATA ANALYTICS TECHNIQUES – I
Agile machine learning approaches for power system data – Unsupervised learning techniques for system behavior analysis – Application of deep learning models in power system monitoring and control.
Activity: Clustering of power system load profiles using unsupervised learning techniques and develop a machine learning pipeline for fault classification or load forecasting using agile methodologies.

DATA ANALYTICS TECHNIQUES – II
Compressive sensing methods for sparse data recovery – Time-series classification techniques – Review of analytics tools and applications using power system datasets – Introduction to R programming for power system analytics.
Activity: Implement compressive sensing techniques for sparse power system data recovery and perform time-series classification using R programming, along with reviewing analytics tools and their applications to real-world power system datasets..

APPLICATIONS OF BIG DATA IN POWER SYSTEMS
Supervised learning methods for fault location – Data-driven techniques for voltage unbalance analysis in distribution networks – Predictive analytics approaches for energy system state estimation.
Activity: Simulations using supervised learning models for fault location in power grids, simulate data-driven voltage unbalance analysis in distribution networks, and apply predictive analytics techniques for simulating energy system state estimation.

DATA ANALYTICS IN ENERGY MARKETS
Analytical methods for energy disaggregation – Use cases and implementation techniques – Addressing the trade-off between utility-level insights and consumer data privacy in energy data analytics.
Activity: Simulations using analytical methods for energy disaggregation, implement selected use cases, and analyze the trade-off between utility-level insights and consumer data privacy in energy data analytics.

References

1. Reza Arghandeh, Yuxun Zhou, “Big Data Application in Power Systems”, Elsevier Science, 2017
2. Ali Tajer, Samir M. Perlaza ,H. Vincent Poor “Advanced Data Analytics for Power Systems”, Cambridge University Press, 2021
3. Hasmat Malik, Md. Waseem Ahmad, D.P. Kothari, “Intelligent Data Analytics for Power and Energy Systems”, Springer, 2022
4. Ahmed F. Zobaa, Trevor J. Bihl, “Big Data Analytics in Future Power Systems”, CRC Press, 2018

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test		
40	60	40	60	200	

	CO Description	PO Mapping	PSO1	PSO2
CO1	Explain the fundamentals of big data concepts, data management frameworks, and privacy challenges in power systems.	-	-	-
CO2	Apply machine learning and deep learning techniques for effective analysis and decision-making in power system operations.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Analyze time-series data using compressive sensing and classification methods, and utilize R programming for power system analytics.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Simulate supervised learning models and predictive analytics for fault detection, voltage unbalance analysis, and state estimation in power networks.	PO1 (3) PO2 (2) PO3 (3)	3	3

CO5	Evaluate and implement data analytics techniques for energy disaggregation while addressing utility-consumer privacy trade-offs.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25C02	FACTS	L	T	P	C
		3	0	0	3

Course Objectives:

- To Understand the concepts of Flexible Power Transmission & describe the principles of shunt & series reactive power compensation to enhance the power flows in conventional power systems.
- To understand the capability of Combined Compensators with reference to exchange of active and reactive power with the power system network.

Introduction to FACTS and Power Flow Control

Overview of power system stability and control needs- Basic types of FACTS controllers: series, shunt, and combined- Benefits and challenges in implementing FACTS devices- Power flow control and voltage regulation using FACTS

Activity: Modeling of SVC and STATCOM in MATLAB/Simulink for reactive power control.

Static VAR Compensator (SVC) and STATCOM

SVC: Configuration, operating principles, and characteristics- STATCOM: V-I characteristics, control strategies, dynamic performance- Comparison between SVC and STATCOM- Reactive power compensation and voltage support.

Activity: Simulation of power flow enhancement using TCSC and UPFC in PSCAD.

Series Compensation using TCSC and SSSC

Thyristor Controlled Series Capacitor (TCSC): operation and control- Sub-Synchronous Resonance (SSR) and mitigation using TCSC- Static Synchronous Series Compensator (SSSC): features and advantages- Power flow control and damping of oscillations using series controllers.

Activity: Comparative analysis of series vs shunt compensation using case study data.

Unified Power Flow Controller (UPFC) and IPFC

Basic operation and control of UPFC- Power flow control using UPFC: modeling and simulation- Interline Power Flow Controller (IPFC): structure and advantages- Control interactions and coordination with other devices.

Activity: Case study analysis of grid stability improvement using FACTS in Indian or global power networks.

Modeling, Simulation, and Application of FACTS

Mathematical modeling and steady-state analysis of FACTS- Dynamic modeling and simulation using MATLAB/Simulink, PSCAD- Integration of FACTS in transmission networks- Case studies and future trends in FACTS deployment

Activity: Integrated control scheme using multiple FACTS devices for power system enhancement.

Weightage:	Continuous Assessment: 40%	End Semester Theory Examination: 60%
	I. Activities: 10% II. Internal Theory Examinations: 30%	

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).

Internal Examinations: TWO tests

References:

1. Narain G. Hingorani and Laszlo Gyugyi, 'Understanding FACTS: Concepts and

Technology of Flexible AC Transmission Systems', IEEE Press, 2000. - Foundational book on theory and practice of FACTS.
2. R. Mohan Mathur and Rajiv K. Varma, 'Thyristor-Based FACTS Controllers for Electrical Transmission Systems', Wiley-IEEE Press, 2002. - Practical insight into thyristor-controlled devices.
3. K. R. Padiyar, 'FACTS Controllers in Power Transmission and Distribution', New Age International, 2nd Edition, 2017. - Indian perspective with emphasis on control and system integration.
4. Song, Yong-Hua, and Allan T. Johns, 'Flexible AC Transmission Systems (FACTS)', IET Power and Energy Series, 1999. - Covers research-based insights and advanced control schemes.
5. IEEE/PES Special Publications and Technical Papers on FACTS applications and developments.

	CO Description	**PO Mapping**	**PSO1**	**PSO2**
CO1	Explain the necessity and functioning of FACTS controllers in modern power systems.	-	-	-
CO2	Differentiate between various FACTS devices and analyze their operational characteristics.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Design and model FACTS devices for power flow control and stability enhancement.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Simulate FACTS devices using tools like MATLAB/Simulink or PSCAD.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Apply FACTS technologies to solve real-world power system problems with improved reliability and efficiency.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25013	Application of AI Techniques to Power System	L	T	P	C
		3	0	0	3

Course Objective:

- To equip students with the knowledge and skills necessary to navigate and contribute to the rapidly evolving landscape of the power sector.
- To demonstrate the relevance and application of various AI techniques within the context of electrical power systems
- To pre-process, analyze, and interpret large datasets from power systems, and to develop and evaluate AI models
- To provide students with the knowledge and skills to integrate renewable energy sources, manage smart grids effectively, and optimize their performance using AI and machine learning
- To explore the ethical considerations, data privacy issues, and cyber security challenges associated with AI in power systems and smart grids.

Introduction to Artificial Intelligence and Power Systems:
Definition of artificial intelligence and its subfields, Expert Systems and Knowledge-Based Systems, Supervised, unsupervised, and reinforcement learning paradigms. Traditional power system architecture and components (generation, transmission, distribution). Challenges and complexities in modern power systems: Grid stability, reliability, efficiency, and integrating renewables.

Activity: Development of fuzzy logic controllers for voltage regulation using MATLAB Fuzzy Toolbox.

Artificial neural networks (ANN):
Biological neuron function and its emulation in artificial neurons, Basic terminology and characteristics of ANNs. Single-layer and multi-layer feed-forward networks, Back propagation learning algorithm, Radial Basis Function Network, Hopfield Network, Recurrent Neural Networks (RNNs) and their variants (LSTMs, GRUs), Convolutional Neural Networks (CNNs).
Gradient Descent and its variants (Momentum, Adam), Vanishing/exploding gradient problem, over fitting, L2 regularization, dropout, Transfer learning. Applications in Power System: Load forecasting (short-term, long-term), Fault detection and diagnosis, Stability analysis and control, Renewable energy forecasting (solar, wind), Power system protection.
Activity:ANN-based load forecasting using Python/Tensor Flow or MATLAB Neural Network Toolbox.

Fuzzy logic and fuzzy systems
Introduction to classical set theory and its limitations in dealing with imprecision, Fuzzy sets: Membership functions and fuzzy set operations. Mamdani and Sugeno fuzzy inference models, Fuzzy rule-based systems and defuzzification methods. Applications in power systems: Reactive power and voltage control, Load frequency control, Fault diagnosis.
Activity: Implementation of PSO for optimal reactive power dispatch.

Genetic Algorithms and Evolutionary Programming:
Natural selection, population, fitness function, reproduction operators, Genetic operators: Crossover (single, two-point, multi-point, uniform, matrix), inversion, deletion, mutation. Applications in power systems: Optimal power flow, Economic load dispatch, Generation and

transmission expansion planning, Optimal placement of FACTs devices and capacitor banks, Hydro-thermal plant coordination. .

Activity: Smart energy management system using AI for a microgrid

Other Machine Learning and AI Techniques

Deep reinforcement learning for stochastic control and optimal decision making, Convolutional Neural Networks for image analysis (e.g., fault detection in visual data). Particle Swarm Optimization (PSO), Differential evolution. Data acquisition: Sensors, smart meters, SCADA systems, Data cleaning, normalization, feature selection, dimensionality reduction. Smart grid management with AI and IoT, Cyber security and data privacy in AI-enabled smart grids.

Activity: Case study analysis of AI applications in real-time SCADA systems.

Text Books

1. Kevin Warwick, Arthur Ekwue, Rag Aggarwal, "Artificial Intelligence Techniques in Power Systems", Institution of Engineering and Technology, 1997.
2. Nagendra Singh (Editor), Sitendra Tamrakar (Editor), Arvind Mewada (Editor), Sanjeev Kumar Gupta, "Artificial Intelligence Techniques in Power Systems Operations and Analysis (Advances in Computational Collective Intelligence)", Auerbach Publications, 2023.
3. Frede Blaabjerg, Weihao Hu, Gouzhou Zhang, Zhenyuan Zhang, Sayed Abulanwar, "AI for Power Electronics and Renewable Energy Systems (Energy Engineering)", Institution of Engineering and Technology, 2024.
4. Juan Miguel Lujano Rojas, Rodolfo Dufo Lopez, Jose Antonio Dominguez Navarro, "Genetic Optimization Techniques for Sizing and Management of Modern Power Systems", Elsevier, 2022.
5. Ioan Gheorghe Ratiu, "The Fuzzy Logic Applications in Power Systems", LAP Lambert Academic Publishing, 2010.

References

1. Fangxing Li, Yan Du, "Deep Learning for Power System Applications: Case Studies Linking Artificial Intelligence and Power Systems (Power Electronics and Power Systems), Springer International Publishing AG; 1st ed. 2024.
2. P. Sanjeevikumar, Sivaraman Palanisamy, Sharmeela Chenniappan, "Artificial Intelligence-based Smart Power Systems", Wiley-IEEE Press; 1st edition, 2022.

activities:

Industrial/Field visit, Seminar, Quiz, Model making, Project development, Poster presentation, Reproduction of research paper in the following categories

- Research, Education, and Training for the AI
- Case Studies and test beds for the AI applications to power system

Assessment Weightage:

Internal Assessment	End Semester Examination	Total
40	60	100

Internal Assessment:

Internal Assessment I (100 Marks)		Internal Assessment II (100 Marks)		Total Internal Assessment	The weighted average shall be converted into 40 marks for internal Assessment
Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test	Individual Assignment / Case Study/ Seminar / Mini Project / any other experiential Learning	Written Test		
40	60	40	60	200	

	CO Description	PO Mapping	PSO1	PSO2
CO1	Understand the fundamental concepts of AI techniques and their relevance to power systems.	PO1 (2) PO2 (2) PO3 (3)	-	-
CO2	Apply AI methods to solve a range of power system problems, including analysis, planning, and operation.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Utilize simulation and software tools (e.g., MATLAB) to implement AI algorithms and analyze results.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Develop innovative solutions using AI and machine learning for sustainable and efficient energy management.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Demonstrate the application of AI in renewable energy forecasting and grid stability.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25014	Cybersecurity of Smart Grids	L	T	P	C
		3	0	0	3

Course Objective:

- The course aims to equip students with essential knowledge and practical skills to analyze, detect, and mitigate cybersecurity threats in smart grids.
- It covers smart grid architecture, data analytics, machine learning, and international cybersecurity standards. Students will learn to design resilient systems, detect cyberattacks like FDI and DoS.
- It explores emerging technologies such as blockchain, federated learning, and quantum-safe cryptography for securing modern power infrastructures.

Foundations of Smart Grids and Cybersecurity

Introduction to Smart Grids: Architecture, Components, and Functions-Communication Technologies and Protocols (SCADA, PMU, AMI, IoT)-Cybersecurity Challenges in Smart Grids-Key Concepts in Cybersecurity: Confidentiality, Integrity, Availability (CIA)-Security Threat Landscape: Vulnerabilities, Threat Vectors, and Attack Surfaces-Smart Grid Cyber-Physical Architecture

Activity: Case study analysis – Analyze recent cyberattacks on smart grids (e.g., Ukraine 2015 Blackout)

Cybersecurity Standards and Frameworks

Overview of Smart Grid Cybersecurity Standards: ISO/IEC 27001, IEC 62351, NIST IR 7628, NERC-CIP - Legal and Regulatory Compliance (GDPR, Indian IT Act, etc.) - Data Privacy and Governance in Smart Grid Infrastructure - Risk Management and Cybersecurity Policies for Utilities - Role of CERTs, Cybersecurity Frameworks (NIST-CSF)

Activity: Create a compliance checklist – Based on IEC 62351/NERC-CIP for a smart grid scenario

Data Analytics for Cyber Threat Detection

Importance of Data in Smart Grid Security Monitoring - Data Preprocessing and Cleaning Techniques - Machine Learning for Threat Detection: Classification (SVM, Random Forest), Clustering (K-Means, DBSCAN) - PMU and AMI Data Analytics - Topology and Fault Detection - Anomaly Detection and Root Cause Analysis

Activity: Hands-on Python or MATLAB session – Build an ML-based anomaly detection model using synthetic PMU/AMI data

Attack Detection and Mitigation in Smart Grids

Types of Attacks: False Data Injection (FDI), Denial of Service (DoS), Load Forecasting Attacks, Replay Attacks - Bayesian and Deterministic State Estimation under Attack - Intrusion Detection Systems (IDS) for Smart Grid - Attack Resilience Mechanisms - Secure State Estimation and Event Localization - Defense-in-Depth Strategy

Activity: Simulate FDI attacks – In MATLAB/Simulink or Python to analyze state estimation impact

Emerging Trends and Resilience in Smart Grid Security

Blockchain for Smart Grid Transactions and Authentication - Federated Learning and Edge AI for Cybersecurity - Quantum-Safe Cryptography in Smart Grids - Digital Twins and Cyber Resilience Modeling - Cybersecurity in Distributed Energy Resources (DERs) and Microgrids - Future Challenges and Research Directions

Activity: Group Seminar or Poster Presentation – On emerging technologies like Blockchain/Quantum Cryptography in smart grids

References:

1. S. Sridhar, A. Hahn, and M. Govindarasu, Cyber-Physical System Security for Smart Grid, Springer, 2016.[ISBN: 9783319449294]
2. NIST IR 7628 Rev. 1: Guidelines for Smart Grid Cybersecurity (2014)
3. K. Liyanage, J. Wu, E. W. Gunawardena, Smart Grid Technology and Data Analytics, Wiley-IEEE Press, 2022.[ISBN: 9781119885036]
4. Y. Mo, T. H.-J. Kim, K. Brancik, et al., "Cyber–Physical Security of a Smart Grid Infrastructure," Proceedings of the IEEE, Vol. 100, 2012.
5. A. Gupta, A. Singhal, Smart Grid Cybersecurity: Security and Privacy Issues, CRC Press, 2020.[ISBN: 9780367334951]
6. Zita Vale, Tiago Pinto, "Intelligent data mining and analysis in power and energy systems",IEEEPress, John Wiley and Sons, first edition, 2023.
7. Ali Tajar, Samir M.Perlaza, H.Vincent Poor, "Advanced data analytics for powersystems", Cambridge University Press, 2021.

E-Resources:

https://www.nist.gov/publications/guidelines-smart-grid-cybersecurity
https://ieeexplore.ieee.org/book/9781119885036

Assessment Weightage:

Quiz and Assignments: 15%
Design/Poster/Seminar Activities: 10%
Simulation Tasks / Case-Based Evaluations: 15%
End Semester Examination: 60%

CO	Description	PO Mapping	PSO1	PSO2
CO1	Understand smart grid architecture, communication, and cybersecurity challenges.	PO1 (2) PO2 (2) PO3 (3)	-	-
CO2	Apply cybersecurity standards and frameworks in smart grid systems.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Implement data analytics to detect anomalies and cyber threats.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Design solutions to detect and mitigate smart grid cyberattacks.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Evaluate emerging cybersecurity technologies for smart grids.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25015	Grid Compliance Study of Inverter Based Resources	L	T	P	C
		3	0	0	3

Course Objectives:

This course aims to

1. Understand the operational principles of inverter-based resources (IBRs) and their interaction with the grid.
2. Analyze grid code requirements and standards for integration of IBRs.
3. Evaluate control strategies for grid-following and grid-forming inverters.
4. Model and simulate compliance issues related to voltage/frequency support, fault ride-through, and harmonics.
5. Develop technical solutions for reliable and stable integration of IBRs into power systems.

Introduction to Inverter-Based Resources (IBRs)

Types of IBRs: solar PV, wind energy systems, battery energy storage- Basic inverter configurations and operating principles- Comparison between synchronous machines and IBRs- Challenges in integrating IBRs into traditional grids

Activity: Simulation of grid-connected PV inverter under LVRT and HVRT conditions using MATLAB.

Grid Codes and Compliance Requirements

Overview of national and international grid codes (IEEE 1547, IEC 61727, CEA regulations)- Voltage and frequency support requirements Fault ride-through (FRT) capabilities and dynamic reactive support- Standards for power quality and harmonic distortion

Activity: Modeling of droop-controlled inverter for voltage and frequency regulation.

Control of Inverter-Based Resources

Grid-following and grid-forming control strategies- Phase-locked loops (PLLs), droop control, and virtual inertia- Anti-islanding protection and grid synchronization- Low voltage ride-through (LVRT) and high voltage ride-through (HVRT) control.

Activity: Comparative study of grid-following vs grid-forming inverters in PSCAD or DIgSILENT.

Modeling, Simulation and Stability Analysis

Dynamic modeling of IBRs in power system analysis tools- Small signal and transient stability assessment with high IBR penetration-Interaction between IBRs and conventional generation- Software tools: MATLAB/Simulink, PSCAD, DIgSILENTPowerFactory.

Activity: Compliance verification of IBRs with IEEE 1547 standards using test cases

Case Studies and Compliance Testing

Case studies of grid integration of utility-scale solar/wind/BESS systems- Pre-certification and compliance testing procedures- HIL testing and inverter response validation- Future trends in grid codes for 100% renewable systems.

Activity: Full system simulation for grid code compliance of a solar-wind hybrid power plant.

Weightage:	Continuous Assessment: 40% III. Activities: 10% IV. Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).

Internal Examinations: TWO tests

References:

1. Narain G. Hingorani and Laszlo Gyugyi, 'Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems', IEEE Press, 2000. - Foundational book on theory and practice of FACTS.
2. R. Mohan Mathur and Rajiv K. Varma, 'Thyristor-Based FACTS Controllers for Electrical Transmission Systems', Wiley-IEEE Press, 2002. - Practical insight into thyristor-controlled devices.
3. K. R. Padiyar, 'FACTS Controllers in Power Transmission and Distribution', New Age International, 2nd Edition, 2017. - Indian perspective with emphasis on control and system integration.
4. Song, Yong-Hua, and Allan T. Johns, 'Flexible AC Transmission Systems (FACTS)', IET Power and Energy Series, 1999. - Covers research-based insights and advanced control schemes.
5. IEEE/PES Special Publications and Technical Papers on FACTS applications and developments.

CO	Description	PO Mapping	PSO1	PSO2
CO1	Explain the operational behavior of inverter-based resources in grid environments.	-	-	-
CO2	Interpret and apply grid code requirements for integrating IBRs.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Design control strategies for grid-following and grid-forming inverters.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Model and simulate grid compliance issues of IBRs using professional tools.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Evaluate case studies and testing procedures for ensuring grid reliability with high IBR penetration.	PO1 (2) PO2 (2) PO3 (3)	3	3

PS25016	Energy Storage Technologies	L	T	P	C
		3	0	0	3

Course Objectives:

This course aims to

1. Understand the role of energy storage in modern power systems and renewable energy integration.
2. Classify and analyze various energy storage technologies and their applications.
3. Model and evaluate the performance characteristics of energy storage systems (ESS).
4. Explore control, sizing, and optimization techniques for ESS in grid and off-grid systems.
5. Study techno-economic aspects and standards related to ESS deployment.

Introduction to Energy Storage Systems

Need for energy storage in power systems and microgrids- Classification of energy storage systems: electrical, electrochemical, mechanical, thermal- Performance metrics: energy density, power density, round-trip efficiency, response time- Applications: frequency regulation, peak shaving, backup, integration of renewable.

Activity: Simulation of lithium-ion battery behavior in MATLAB/Simulink including SoC estimation.

Electrochemical Energy Storage

Battery types: Lead-acid, Lithium-ion, Nickel-metal hydride, Flow batteries- Battery characteristics, charging/discharging, life cycle and safety- Battery Management Systems (BMS) and state-of-charge (SoC) estimation- Recent trends in battery technology for grid and EV applications.

Activity: Design and modeling of Battery Management System (BMS) with temperature control.

Mechanical and Thermal Storage Technologies 9

Flywheel energy storage systems (FESS) – construction and applications- Compressed Air Energy Storage (CAES), Pumped Hydro Storage (PHS) – operational principles- Thermal energy storage (TES): sensible, latent, and thermochemical storage- Hybrid energy storage systems.

Activity: Sizing of hybrid battery-supercapacitor ESS for EV or microgrid applications.

Power Electronics and Control of Energy Storage 9

Converters and interfaces for energy storage integration- Charge/discharge control strategies- Grid-tied vs standalone control configurations- Sizing and optimization of ESS for specific applications.

Activity: Sizing of hybrid battery-supercapacitor ESS for EV or microgrid applications.

Applications, Standards, and Future Trends 9

Use of ESS in renewable integration, smart grid, EV charging, and islanding systems- IEEE/IEC standards and codes for ESS (IEEE 2030.2, UL 9540, etc.)- Techno-economic analysis: lifecycle cost, ROI, policy frameworks- Emerging storage technologies: supercapacitors, hydrogen, solid-state batteries.

Activity: Comparative techno-economic analysis of ESS options for rural microgrid electrification.

Weightage:	Continuous Assessment: 40% V. Activities: 10% VI. Internal Theory Examinations: 30%	End Semester Theory Examination: 60%

Mandated Activities with marks: Assignments (30), Quiz (10), Virtual demonstration (25), Flipped Classroom (10), Review of GATE & IES questions (25).

Internal Examinations: Two tests

References:

1. A.G. Ter-Gazarian, 'Energy Storage for Power Systems', 2nd Edition, IET, 2011. – A foundational text on all major storage technologies.
2. R. T. Lund, 'Electrical Energy Storage Technologies: Global Markets', CRC Press, 2020. – Market and technical overview.
3. James M. Eyer and Garth P. Corey, 'Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment', Sandia National Laboratories Report, 2010.
4. Francois Bouchard, 'Power Electronics for Renewable and Distributed Energy Systems', Springer, 2013 – Power electronic interfaces and control.
6. IEEE Standards 1547, 2030.2, UL 9540 – Regulatory frameworks for energy storage systems developments.

	CO Description	PO Mapping	PSO1	PSO2
CO1	Explain the operational principles and classifications of energy storage systems.	-	-	-
CO2	Analyze performance and characteristics of different battery and non-battery storage technologies.	PO1 (3) PO2 (1) PO3 (3)	3	3
CO3	Design control systems and interface electronics for ESS integration.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO4	Evaluate the economic and regulatory aspects of deploying ESS in grid applications.	PO1 (3) PO2 (2) PO3 (3)	3	3
CO5	Apply simulation tools for ESS modeling, sizing, and performance analysis.	PO1 (2) PO2 (2) PO3 (3)	3	3