भारतीय प्रौद्योगिकी संस्थान जोधपुर

Indian Institute of Technology Jodhpur

M.Tech.

in

Power Systems and Power Electronics

Department of Electrical Engineering

Indian Institute of Technology Jodhpur, Jodhpur

New Postgraduate Program :

M.Tech. in Power Systems and Power Electronics

[Department of Electrical Engineering]

Indian Institute of Technology Jodhpur, Jodhpur

1. Background:-

The power sector is experiencing rapid transformation with the large-scale integration of renewable energy sources, expansion of electric mobility, deployment of distributed generation, and modernization of transmission and distribution networks. These developments are reshaping conventional power systems into complex, dynamic, and converter-dominated networks. As a result, the boundaries between power systems and power electronics are increasingly interconnected.

Modern power systems rely heavily on power electronic converters for renewable energy integration, high-voltage DC transmission, flexible AC transmission systems, energy storage interfacing, microgrids, and electric vehicle charging infrastructure. At the same time, stable and reliable grid operation requires advanced system analysis, protection strategies, optimization techniques, and intelligent control frameworks. Therefore, future power engineers must possess strong foundations in both large-scale power system operation and advanced power electronic converter technologies.

The proposed M.Tech. program in Power Systems and Power Electronics is designed to address this interdisciplinary need. The program aims to develop professionals with in-depth knowledge of power generation, transmission, distribution, system stability, and protection, along with expertise in power converters, electric drives, control techniques, and grid-interfaced systems. By integrating analytical rigor with laboratory training, simulation-based studies, and research exposure, the program will prepare graduates to contribute effectively to sustainable energy systems, smart grids, electric transportation, and next-generation power infrastructure.

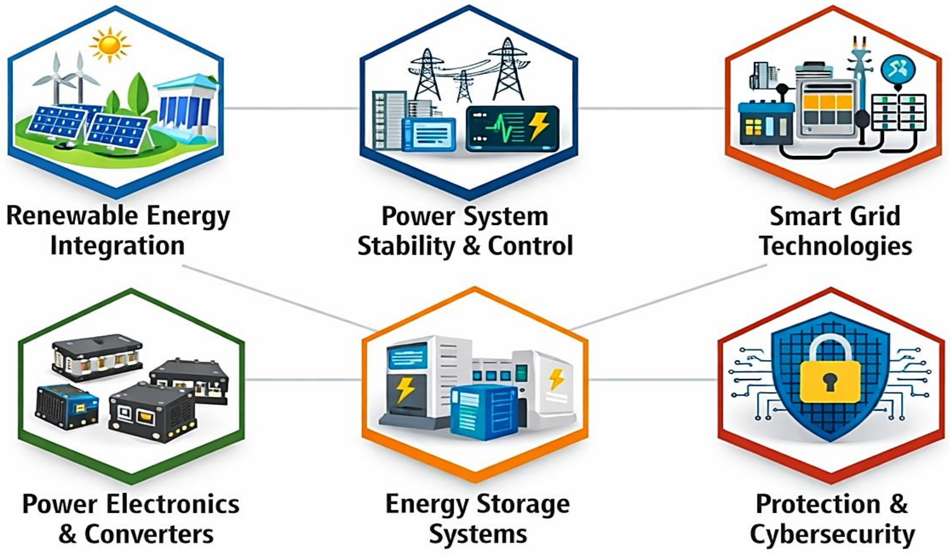

Fig.1 Core Research area of M.Tech. in Power Systems and Power Electronics.

⇒ Course Duration

Program Title	Program Duration	Degree Name
M.Tech. in Power Systems and Power Electronics	2 Years (M.Tech.)	M.Tech. (Regular)

⇒ The Eligibility criteria for M. Tech. in Power Systems and Power Electronics

Qualifying Degree		GATE Requirements
With Fellowship	B. Tech., B.E. or B.Sc. (Engineering) in Electrical Engineering / Electrical and Electronics Engineering/Power Engineering or allied discipline	Valid GATE score in EE
	B. Tech., B.E. or B.Sc. (Engineering) in Electrical Engineering / Electrical and Electronics Engineering/Power Engineering or allied discipline from any of the CFTIs with CPI or CGPA of 8/10 or above	The requirement of valid GATE score is exempted
Without Fellowship	B. Tech., B.E. or B.Sc. (Engineering) in Electrical Engineering / Electrical and Electronics Engineering/Power Engineering or allied discipline, with CPI or CGPA of 6/10 or above	Written test & Interview

2. Objectives of the Program:-

- **Industry Demand**
  - Power Utilities & Grid Operators (NTPC, POWERGRID, Siemens, ABB) need experts in smart grid automation, stability analysis, and renewable energy integration.
  - EV & Semiconductor Industry (Tesla, Ola Electric, Texas Instruments, Infineon) seeks engineers skilled in high-efficiency power converters, motor drives, and battery management systems.
  - Defense & Space (DRDO, ISRO, HAL) requires specialists in ruggedized power systems, energy storage, and cyber-resilient grid architectures.

- **Research & Innovation Potential**
  - AI/ML for Power Systems: Predictive maintenance, fault detection, energy forecasting, planning and operation.
  - Next-Gen Power Electronics: Wide-bandgap semiconductors (SiC, GaN), high-frequency converters.
  - Cyber-Physical Security: Protecting smart grids from cyberattacks and false data injection.
  - Vehicle-to-Grid (V2G) Technologies: Enabling EVs to stabilize grid demand.

- **Strategic Importance for India**
  - Supports India’s net-zero emissions goal by training engineers in clean energy technologies.
  - Aligns with National Smart Grid Mission, FAME-II (EV policy), and Atmanirbhar Bharat in power electronics manufacturing.
  - Evolving electricity markets, cross-border power trading, Grid scale BESS integration.

- **Unique Program Features**
  - Dual Degree Option (M.Tech.-Ph.D.) for research-oriented students.
  - Executive Mode (Weekend/Evening Classes) for working professionals.
  - Industry-Aligned Curriculum with Siemens, ABB, and ISRO collaborations.
  - State-of-the-Art Labs for real-time grid simulation, EV testing, and power electronics prototyping.

⇒ **Existing Facilities:**

- **Power Systems Lab:** Real-time simulators (OPAL-RT), Typhoon HIL, Protection Relay Setups and Synchrophasors.
- **Power Electronics Lab:** SiC/GaN-based converters, oscilloscopes and probes.
- **Motor Drives Lab:** IM test benches, control hardware.
- **Software Tools:** MATLAB, Typhoon.
- **Rishabh Centre for Research and Innovation in Clean Energy** (Solar Simulator, Microlab Box, Inverters, RTDS, Power Quality Analyser, etc)
- **Equipments through HEFA** (Power Network Simulator, Microgrid Test Kit, Solar Array Simulation, Realtime Controllers, etc.)

3. Graduate Attributes:-

- **Core Competencies:**
  - Power system analysis (load flow, stability, economic dispatch).
  - Design and control of power electronic converters (SiC/GaN-based).
  - Modeling and optimization of electric drives for industrial and automotive applications.
- **Technical Proficiencies:**
  - Simulation tools: MATLAB/Simulink, PSCAD, Python, Typhoon HIL, OpenDSS.
  - Hands-on labs: Real-time grid simulations, motor drive testing, converter prototyping.
  - Cleanroom fabrication and PCB design for power electronics.
- **Industry-Aligned Skills:**
  - Smart grid communication protocols (IEC 61850, DNP3).
  - Cybersecurity frameworks for power systems.

4. Learning Outcomes:-

- **Advanced Power Systems:**
    - Smart grid technologies, wide-area monitoring (WAMS), and microgrids.
    - Renewable energy integration (solar, wind, hybrid systems) and grid stability.
    - Cybersecurity for critical power infrastructure.
    - Modern Power System Protection and Electricity Markets.
- **Electric Drives and Motion Control:**
    - High-performance motor drives for EVs and industrial automation.
    - Sensorless control, vector control, and direct torque control strategies.
- **Power Electronics and Energy Conversion:**
    - Design of high-efficiency converters (DC-DC, inverters, PFC circuits).
    - Applications in EV chargers, renewable energy systems, and grid interfaces.
- **Emerging Technologies:**
    - AI/ML for predictive maintenance, fault detection, and energy forecasting.
    - Battery energy storage systems and vehicle-to-grid (V2G) technologies.

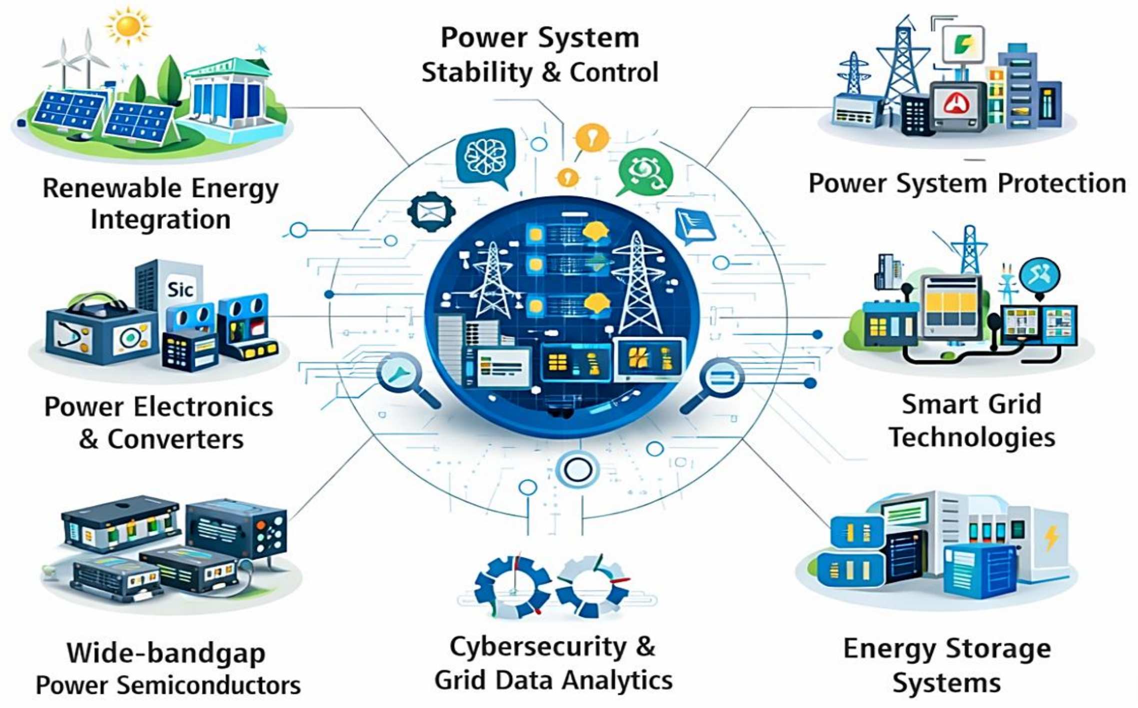

Fig.2 Major Research Domain of M.Tech. in Power Systems and Power Electronics.

⇒ **Career Opportunities**

Graduates can work in:

- **Power Sector:** NTPC, POWERGRID, Tata Power.
- **EV & Renewable Energy:** Tesla, ReNew, SunPower.
- **Semiconductor & Electronics:** Texas Instruments, Infineon, STMicroelectronics.
- **Defense & Aerospace:** DRDO, HAL, ISRO.
- **Research & Academia:** IITs, NITs, global universities.

5. Program Structure:-

Category	M. Tech. Compulsory (C)	M. Tech. Elective (E)	M. Tech. Thesis (T)	Non-graded (NG)	Total Graded
Credits	**13**	**12**	**40**	**NG**	**65**

6. Semester-wise Distribution of Credits:-

M. Tech. (Regular) : M.Tech. in Power Systems and Power Electronics

Cat.	*Course Number & Title*		*L-T-P*	*Credits*		*Cat.*	*Course Number & Title*		*L-T-P*	*Credits*
I Semester						**II Semester**				
C	EEL7XX0	Computational Methods in Power System Analysis	3-0-0	3		C	EEL7XX0	Advanced Control System	3-0-0	3
C	EEL7XX0	Electric Drive Systems	3-0-0	3		E	EEL7XX0	Elective	3-0-0	3
C	EEL7XX0	Power Electronic Converters	3-0-0	3		E	EEL7XX0	Elective	3-0-0	3
C	EEL7XX0	Integrated Power & Drives Laboratory	0-0-2	1		E	EEL7XX0	Elective	3-0-0	3
E	EEL7XX0	Elective	3-0-0	3		NG	LEN7XX0	Innovation and IP Management	1-0-0	S/U
NG	LEN7XX0	Technical Communication	1-0-0	S/U						
Total				**13**		Total				**12**
Summer Semester										
T	EET7XX0	Summer Thesis		8						
Total				**8**						
III Semester						**IV Semester**				
T	EET7XX0	Thesis		16		T	EET7XX0	Thesis		16
Total				**16**		Total				**16**

Note: "The thesis work must be aligned with the objectives of the enrolled program as stated in the concept note."

7. List of Courses:

- **Electives:**

S. No.	Course Code	**Course Name**	*L-T-P*	*Credits*
1	CSL7XX0	Machine Learning	3-0-0	3
2	CSL7XX0	Deep Learning	3-0-0	3
3	EEL7XX0	Introduction to Smart Grid	3-0-0	3
4	EEL7XX0	Renewable Energy Systems	3-0-0	3
5	EEL7XX0	Power System Protection	3-0-0	3
6	EEL7XX0	Modern Power System Operation and Control	3-0-0	3
7	EEL7XX0	Special Drives for Electric Vehicles	3-0-0	3
8	EEL7XX0	Introduction to Cyber-Physical Systems	3-0-0	3
9	EEL7XX0	HVDC & FACTS	3-0-0	3
10	EEL7XX0	Introduction to High Voltage Engineering and Dielectric Breakdown	3-0-0	3
11	EEL7XX0	Optimization Methods for Power System	3-0-0	3
12	EEL7XX0	Control Techniques in Power Engineering	3-0-0	3

8. Detailed Course Contents:-

Title	**Electric Drive Systems**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech., M.Tech., Ph.D.	Type	C
Prerequisite	Knowledge of Electrical Machines and Power Electronics		

Objectives

1. Provide fundamental understanding of electric drive systems, load characteristics, and drive dynamics for industrial applications.
2. Develop analytical and modelling skills for DC, Induction, and Synchronous motor drives under dynamic conditions.
3. Introduce modern power electronic converters and control strategies including PWM, vector control, and digital implementation.
4. Enable students to analyse and design high-performance motor drive systems for industrial automation and EV applications.
5. Expose students to special and emerging electric machines such as SRM, stepper motors, axial flux motors, and their control techniques.

Learning Outcomes

1. **Understand the Fundamentals of Electric Drives**: Explain the principles of AC and DC drive systems, including machine structures, driver topologies, and power electronic interfaces.
2. **Analyse and Control Electric Machines:** Evaluate the operation and control of various electric machines, including induction motors, synchronous motors, switched reluctance motors, and PMSM/BLDC.
3. **Apply Drive Control Techniques**: Implement control strategies such as vector control, field-oriented control, direct torque control, and sensorless operation for electric motor drives.
4. **Design and Evaluate Motor Drive Systems**: Assess the performance of DC/DC converter-based motor control, and inverter-driven induction and synchronous motor drives.
5. **Compare and Select Motor Drives for Applications:** Critically compare DC, IM, PMSM, SRM, and special machines in terms of performance, efficiency, controllability, and industrial suitability, including EV traction systems.

Contents

- **Introduction to Electric Motor Drives (04 Lectures)**
  Importance of drives, Factors governing the choice of drives, Basics of drive dynamics, Types of load, Selection of motor power rating, Applications.

- **DC Motor Drives (06 Lectures)**
  Types of dc motors, starting and braking, transient analysis of separately excited motor with armature and field control, Control of electric drives, Multi-quadrant & regenerative operation, closed loop torque, speed and position control, current and speed sensing, Chopper controlled dc drives.

- **Induction Motor Drives (12 Lectures)**
  Starting & Braking of Induction Machines (Classical Methods): DOL, star-delta, autotransformer starting, Rotor resistance control, Plugging, Modelling of Induction Motor for Drives: Dynamic model in dq reference frame, State-space equations, Torque equation, Slip and rotor flux dynamics,VSI-Fed Induction Motor Drives: PWM inverter operation, SPWM & Space Vector, PWM, DC-link considerations, Regenerative operation,Scalar Control (V/f Control): Stator voltage control, Constant V/f principle, Open-loop vs closed loop, Field weakening region, Industrial VFDs, Vector Control (Field-Oriented Control – FOC): Principle of decoupling torque & flux, Rotor flux oriented control, Current control loops, Implementation structure,Direct Torque Control (DTC): Basic concept, Hysteresis controllers, Comparison with FOC, Torque ripple & switching frequency trade-offs,Advanced Topics / Industry Integration: Introduction to Sensorless control, Model predictive control, Industrial VFD architecture, EV traction comparison (IM vs PMSM).

- **Synchronous Motor Drives (12 Lectures)**
  Types of synchronous motors – Cylindrical-rotor and Salient-pole motors, Converter-fed synchronous motor drive dynamics and advanced digital control, Modelling of Synchronous Machines for Drive Applications: dq-axis modelling (Park's transformation), State-space equations, Electromagnetic torque derivation, Power flow,Power Electronic Converter Fed Operation: VSI-fed synchronous motor, PWM and Space Vector PWM (SVPWM), Current control techniques,Vector Control (Field Oriented Control – FOC):

Decoupled torque & flux control, Current regulators (PI-based), Implementation architecture (DSP-based control),PMSM Drives: Surface vs Interior PMSM, Torque equation, Maximum torque per ampere (MTPA), Flux weakening control, Applications in EVs & robotics,BLDC Drives (Application-Oriented): Electronic commutation, Hall sensor & sensorless control, Six-step vs sinusoidal control, Comparison with PMSM.

6. **Introduction to Special Machines (5 Lectures):**

Switched Reluctance Motor (SRM) drives:

Fundamentals: Construction & doubly salient structure, Torque production mechanism (reluctance torque), Static torque characteristics, Inductance profile, Power Converter & Control: Asymmetric bridge converter, Current profiling, Torque ripple issue, Basic closed-loop control, Modern Developments: Torque ripple minimization techniques, Sensorless SRM control, Application in EVs & aerospace, Comparison with PMSM & IM.

Stepper Motors & Precision Motion Control

Stepper Motor Fundamentals: Variable reluctance stepper, Hybrid stepper motor, Step angle & resolution, Open-loop control, Advanced Control: Microstepping, Closed-loop stepper control, Resonance & vibration issues, Applications in CNC, robotics, 3D printers.

Emerging Special Machines: Axial flux motors (important for EVs) and Flux switching machines.

Textbook

a. *Fundamentals of Electric Drives*", Gopal K Dubey, Narosa, 2nd Ed., ISBN: 978-81-7319-428-3, 2022.
b. *Power Semiconductor Controlled Drives",* Gopal K Dubey, *Prentice Hall International Edition. 1989.*
c. *Electric Motor Drives: Modeling, Analysis, and Control*, By: R. Krishnan, 1st Edition, Prentice Hall ISBN: 0-13-091014-7, 2001.

Reference Books

1. *Fundamentals of Electric Drives*, By: M. A. El-Sharkawi, 1st Edition, PWS Pub. Co., ISBN: 0-534-95222-4 2000.
2. *NPTEL Fundamentals of Electric Drives* by Prof. S. P. Das, EE Dept., IIT Kanpur.
3. *Control of Electrical Drives,* W. Leonhard, Springer, 3rd ed. 2001.
4. *Sensorless Vector and Direct Torque Control*, P. Vas, S, Oxford University Press, 1998.
5. *Power Electronics and AC Drives,* B. K. Bose, Prentice Hall, 1986.
6. *Analysis of Electric Machinery and Drive Systems", Krause, P. C., Wasynczuk, O., Sudhoff, S. D.,, New York Wiley-Interscience, 2002.*

Title	**Power Electronic Converters**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech., B.Tech., Ph.D.	Type	C
Prerequisite	Basic Electrical Engineering		

Objectives

The instructor will:

Introduce to various power-switching devices and their control. Introduce various power electronic circuits for realization of AC-DC, AC-AC, DC-AC, DC-DC conversion, operation principle, analysis, pulse-width modulation and pulse frequency control of power electronic converters, design problems on power electronic converter systems..

Learning Outcomes

The students are expected to have the ability to:

- Learning of PWM techniques in DC-DC conversion, new circuit topologies, steady-state analysis methods and their design aspects, and their application to Inverter, UPS, etc,.
- Learning of PWM techniques in DC-AC conversion, new inverter circuit topologies, steady-state analysis methods and their design aspects, and their application to Advanced Inverters, UPS, etc,.
- Learning of AC-AC conversion systems and their control schemes, new circuit configurations, steady-state analysis methods and design aspects, and their application to Advanced drives and motion control.

Contents

Component Characteristics of Power Electronics [3 Lectures] : Review of power semiconductor switching devices, Thyristors, MOSFET, IGBT,and modern devices, characteristics and applications.

Basics of operating modes [4 Lectures]: Introduction to Turn-ON/Turn-OFF mechanism of switching devices, Gate-drive circuits, Switching-aid circuits, protection, Heat sink design.

Rectifier Circuits and Operation [8 Lectures]: Line-commutated rectifiers, single and three-phase rectifiers (controlled/uncontrolled), performance analysis, harmonics, Ripple reduction techniques, Introduction to multi-pulse converters.

Operations of DC-to-DC Converters [9 Lectures]: Switch-mode DC-DC Converters, pulse width modulation, Nonisolated and isolated Topologies, continuous and discontinuous modes of operations, steady-state analysis, energy storage elements design, higher-order topologies.

Operations of AC-to-DC /DC-to-AC Inverters [10 Lectures]: Inverters, single and three-phase inverter configurations, voltage and current source inverters and their operating modes, voltage control in inverters and harmonic reduction using PWM strategies, Introduction to Multi-level Inverters, applications.

Operations of AC-to-AC Converters [5 Lectures]: AC-AC voltage controllers, configurations, performance analysis, harmonics, Cyclo-converters, introduction to Matrix converters and their applications.

Textbook

- Fundamental of Power Electronics: Robert Erickson, D. Maksimovic

Reference Books

1. Power Electronics, Circuits, Devices and Applications: Muhammad H. Rashid
2. Power Electronic, Devices, Applications, and Passive Components: Barry W. Williams
3. Power Electronics - converters, Applications, and Design: Ned Mohan, Tore. M. Undeland, William P. Robbins

Title	**Computational Methods in Power System Analysis**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech., B.Tech., Ph.D.	Type	C
Prerequisite	Power System Analysis, Basic Numerical Methods		

Objectives

The objective of this course is to develop a strong foundation in computational and numerical techniques used in power system analysis. It focuses on modeling, load flow, fault, stability, and contingency analysis using efficient algorithms suitable for large-scale modern power networks.

Learning Outcomes

After completing this course, students will be able to:

1. Model power system components and formulate network equations.
2. Apply various load flow and contingency analysis methods for system planning and operation.
3. Perform fault and stability analysis for interconnected power systems.
4. Use advanced numerical and computational techniques to analyze large-scale power networks.

Contents

Module 1: Power System Modeling and Network Formulation (4 Hours) Per-unit system and network representation - Formation of Y-bus matrix with sparse structure - Graph-theoretic interpretation of power networks - Modeling power system components (steady-state representation).

Module 2: Load Flow Analysis (11 Hours) Power flow problem formulation using power mismatch and current injection mod- els - Gauss-Seidel method - Newton-Raphson method- Fast Decoupled Load Flow - DC Power Flow formulation and applications - Distribution system load flow using Back- ward/Forward Sweep and DistFlow equations.

Module 3: Security and Contingency Analysis (6 Hours) N-1 security criterion - Contingency screening and ranking - Performance indices - Power Transfer Distribution Factors (PTDF) - Line Outage Distribution Factors (LODF) - Fast contingency evaluation using DC power flow.

Module 4: Fault Analysis (5 Hours) Symmetrical fault analysis - Unsymmetrical faults using sequence components - Z-bus formulation for short-circuit studies - Short-circuit analysis in large-scale interconnected systems.

Module 5: Stability Analysis (8 Hours) Rotor angle stability and swing equation - Equal area criterion - Multi-machine sys- tem modeling - Linearization of differential-algebraic equations and eigenvalue analysis - Voltage stability and continuation power flow.

Module 6: Advanced Computational Techniques in Power System Analysis (5 Hours) Numerical conditioning and scaling in large power networks - Sparse matrix stor- age schemes and computational efficiency - Sensitivity analysis of power flow solutions - Properties of the Jacobian matrix - Iterative and direct solution methods - Computational aspects of time-domain simulation.

Textbook

- P. Kundur, Power System Stability and Control.

Reference Books

1. J. Grainger and W. Stevenson, Power System Analysis.
2. A. J. Wood, B. F. Wollenberg and G. B. Sheble, Power Generation, Operation, and Control.
3. H. Saadat, Power System Analysis.
4. Selected research papers.

Title	**Integrated Power & Drives Laboratory**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [C]	0-0-2 [1]
Offered for	M.Tech., B.Tech., Ph.D.	Type	C
Prerequisite	Power System Analysis, Power Electronics		

Objectives

The objective of this laboratory course is to provide students with hands-on experience in the analysis and operation of power systems, power electronic converters, and electric drives. Through a series of experiments involving load flow studies, short-circuit analysis, PMU-based monitoring, rectifiers, DC–DC converters, inverters, PWM techniques, and motor control methods, students will gain practical knowledge of system behavior, control strategies, and performance evaluation, thereby strengthening their understanding of modern electrical power engineering concepts and applications.

Learning Outcomes

Upon successful completion of this laboratory course, students will be able to analyze, model, and evaluate the performance of power systems, power electronic converters, and electrical drives using modern simulation and experimental tools. They will develop the ability to perform load flow and fault analysis, monitor power system conditions, investigate converter characteristics, implement motor control techniques, and interpret results to solve practical engineering problems related to power generation, transmission, distribution, and industrial drive applications.

Contents

- Load Flow Analysis using Gauss–Seidel Method
- Load Flow Analysis using Newton–Raphson Method
- Short Circuit Analysis of a Power System Network
- PMU-Based Power System Monitoring and Fault Detection
- Performance Analysis of Single-Phase Fully Controlled Rectifier
- Operation of DC–DC Buck Converter
- Operation of DC–AC Inverter
- PWM Generation and Analysis for Voltage Source Inverter
- Speed Control of DC Motor using Chopper Drive
- V/f Control of Three-Phase Induction Motor Drive.

(The above list of experiments is tentative and may be revised periodically in accordance with industry requirements, recent research developments, and the availability of laboratory facilities.)

Textbook

- J. Grainger and W. Stevenson, Power System Analysis.

Reference Books

- P. Kundur, Power System Stability and Control.
- A. J. Wood, B. F. Wollenberg and G. B. Sheble, Power Generation, Operation, and Control.
- H. Saadat, Power System Analysis.
- Selected research papers.

Title	**Modern Power System Operation and Control**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [E]	3-0-0 [3]
Offered for	M.Tech., B.Tech., Ph.D.	Type	E
Prerequisite	Power System Analysis, Control Systems, Basic Numerical Methods, Introductory Optimization Techniques		

Objectives

This course aims to provide advanced understanding of modern power system operation, optimization, and control. It covers economic dispatch, optimal power flow, load frequency and voltage control, state estimation, and security assessment. The course also addresses operational challenges arising from renewable energy integration, uncertainty, and market-based frameworks.

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Formulate and solve economic dispatch, unit commitment, and optimal power flow problems.
2. Analyze load frequency and voltage control in interconnected power systems.
3. Apply state estimation and monitoring techniques for reliable system operation.
4. Evaluate system security and contingency management strategies.
5. Assess the impact of renewable energy and market mechanisms on power system operation.

Contents

Module 1: Economic Operation of Power Systems (8 Hours) Economic dispatch formulation - Transmission loss modeling and penalty factors - Unit commitment problem formulation - Hydro-thermal coordination - Classical solution methods - Introduction to security constrained economic dispatch.

Module 2: Optimal Power Flow (8 Hours) DC Optimal Power Flow formulation - AC OPF formulation - Equality and inequality constraints - Interior point methods overview - Security constrained OPF - Introduction to convex relaxations.

Module 3: Power System Control (7 Hours) Automatic Generation Control (AGC) - Load frequency control in single and multi- area systems - Tie-line power control - Governor and turbine models - Excitation systems and voltage control - Reactive power and voltage control mechanisms.

Module 4: Power System State Estimation and Monitoring (6 Hours) Measurement modeling - Weighted Least Squares state estimation - Observability analysis - Bad data detection and identification - Phasor Measurement Units (PMUs) - Introduction to dynamic state estimation.

Module 5: Security and Operational Planning (5 Hours) Security assessment in operational time frame - Preventive and corrective control actions - Remedial action schemes - Contingency constrained operation - Introduction to ancillary services.

Module 6: Modern Topics in Power System Operation (5 Hours) Operation with renewable energy sources - Forecasting and uncertainty in system op- eration - Demand response and distributed energy resource coordination - Market-based operation and locational marginal pricing - Overview of Energy Management Systems.

Textbook

- A. J. Wood, B. F. Wollenberg, and G. B. Sheble, Power Generation, Operation, and Control, 3rd ed., Wiley, 2013.

Reference Books:

1. P. Kundur, Power System Stability and Control, McGraw-Hill, 1994.
2. A. Abur and A. G´omez Expo´sito, Power System State Estimation: Theory and Implementation, CRC Press, 2004.
3. A. J. Conejo, M. Carrio´n, and J. M. Morales, Decision Making Under Uncertainty in Electricity Markets, Springer, 2010.
4. S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004.

Title	**Optimization Methods for Power System**	Number	EEL7xx
Department	Electrical Engineering	L-T-P [E]	3-0-0 [3]
Offered for	B.Tech./M.Tech./PhD	Type	E
Prerequisite	Coding skills in any one language (MATLab, Python, C, Or C++)		

Objectives

The Instructor will:

- **Introduce Metaheuristic Concepts**: Aim to provide a comprehensive understanding of metaheuristic algorithms, including their principles, types, and applications in optimization.
- **Explore Advanced Techniques**: Delve into advanced metaheuristic techniques, such as hybridization, parallelization, and adaptation, to enhance optimization performance.
- **Foster Critical Thinking**: Encourage to analyze and evaluate the effectiveness of various metaheuristic algorithms in solving complex optimization problems.

Learning Outcomes

The students are expected to have the ability to:

- **Apply Metaheuristic Algorithms**: To be able to select and apply appropriate metaheuristic algorithms to solve real-world optimization problems.
- **Analyze Algorithm Performance**: To be able to analyze the performance of metaheuristic algorithms in terms of convergence rate, solution quality, and computational efficiency.
- **Design New Metaheuristics**: To have the ability to design novel metaheuristic algorithms or hybridize existing ones to address specific optimization challenges.

Contents:

Introduction to Optimization [4 lectures]: Definition and significance of optimization Types of optimization problems (single variable, multivariable, constrained, unconstrained) Overview of metaheuristic optimization as a solution approach.

Single Variable Optimization [4 lectures]: Problem formulation for single variable optimization Classical optimization methods (e.g., golden section search, bisection method) Application of metaheuristic algorithms to single variable optimization problems.

Multivariable Optimization [6 lectures]: Problem formulation for multivariable optimization Gradient-based optimization methods (e.g., gradient descent, Newton's method) Metaheuristic approaches for multivariable optimization (e.g., genetic algorithms, particle swarm optimization).

Constraint Handling Techniques [4 lectures]: Classification of constraints in optimization problems (equality, inequality, mixed) Penalty function methods Constraint handling in metaheuristic optimization algorithms.

Evolutionary Algorithms [5 lectures]: Introduction to evolutionary algorithms (EAs) Genetic algorithms (GAs) for optimization Differential evolution (DE) for optimization.

Swarm Intelligence [6 lectures]: Overview of swarm intelligence algorithms Particle swarm optimization (PSO) Ant colony optimization (ACO).

Simulated Annealing [3 lectures]: Concept and principles of simulated annealing Simulated annealing for constrained optimization problems Applications of simulated annealing in real-world problems.

Tabu Search [2 lectures]: Fundamentals of tabu search Tabu search strategies for optimization Hybrid metaheuristic algorithms incorporating tabu search.

Hybrid and Adaptive Metaheuristics [5 lectures]: Hybrid metaheuristic optimization techniques Adaptive metaheuristic algorithms Case studies demonstrating the effectiveness of hybrid and adaptive approaches.

Textbook

- Deb K., Optimization for Engineering Design – Algorithms and Examples, Prentice Hall of India Pvt. Ltd., New Delhi, 1995.
- R. Fletcher, Practical Methods of Optimization, 2nd edition, Wiley, 2000.

Reference Book:

- Dan Simon, Evolutionary Optimization Algorithms, Wiley, 2013.

Title	**Special Drives for Electric Vehicles**	Number	EEL7710
Department	IDRP: Robotics & Mobility Systems	L-T-P [E]	3-0-0
Offered for	-	Type	E
Prerequisite	-		

Objectives

1. The instructor will provide exposure on different types of machines for EV applications, its control technique as well as the architecture of electric vehicles.

Learning Outcomes

1. Different types of motor and their control technique for electric vehicle application.
2. Selection procedure of electric drives, according to the electric vehicle's architecture, application, and energy supply system.

Course Content

Introduction [6 lectures]: Introduction to EVs, Classification of EVs, and Working Principle of EVs.

Configurations and components of electric drives [8 lectures]: Basics of Electric Propulsion System, Transmission System, Energy Management System, Energy Source, and Auxiliary Power System.

Architectures of EVs [3 lectures]: Different types of architectures based on electric propulsion and energy sources.

DC Series Motor [4 lectures]: Voltage Equation, Back EMF, Condition for Maximum Mechanical Power, Armature Torque of DC Motor, Relation of Speed with Back Emf and Flux, Characteristic and Speed Control of DC Series Motors, Electric Breakings of DC Series Motors.

Brushless DC Motor (BLDC) [4 Lectures]: Classification, Construction, Electronic Commutation, Principal of Operation, Microprocessor/DSP Based Control Scheme of BLDC Motor, Sensor Less Control, Comparison with DC Series Motor.

Permanent Magnet Synchronous Motor (PMSM) [4 Lectures]: Principle of Operation, EMF Calculation, Power Input and Torque Expressions, Torque and Speed Relation, Phasor Diagram. Power Controllers, and Torque Speed Characteristics.

Three Phase AC Induction Motor [4 Lectures]: Introduction and Construction, Rotor EMF & Frequency, Current and Power, Power Stages, Phasor Diagram, Analysis of Equivalent Circuit, Torque-Speed Characteristics in Braking, Motoring and Generating Regions. Effect of Voltage and Frequency Variations on Induction Motor Performance, Losses and Efficiency, No Load and Block Rotor Test, Speed Control Methods Including V/F Method, Starting Methods, Cogging and Crawling.

Switched Reluctance Motors (SRM) [4 Lectures]: Basics of SRM Analysis, Constraints on Pole Arc and Tooth Arc, Torque Equation and Characteristics, Power Converter Circuits, Control of SRM, Rotor

Position Sensors, Current Regulators, Sensorless Control of SRM, Relationship in-between Torque, Speed and Input Power.

Synchronous Reluctance Motor (Syrm) [4 Lectures]: Principle and Construction of Synchronous Reluctance Based Drive, Operating Condition and Power Factor of Synchronous Reluctance Motors, Constant Power Operation, Permanent Magnet Reluctance Motors, Torque and Speed Relationship.

Textbook

- P. S. Bimbhra, (1977), Electrical Machinery, KHANNA PUBLISHERS, Seventh edition, (1 January 1977).

Reference Book

- D. P. Kothari, and I. J. Nagrath, (2017), Electric Machines, McGraw Hill Education; Fifth edition, (23 June 2017).

Title	Introduction to High Voltage Engineering and Dielectric Breakdown	Number	EEL7xx
Department	Electrical Engineering	L-T-P [E]	3-0-0 [3]
Offered for	B.Tech./M.Tech./PhD	Type	E
Prerequisite	Basic Electrical Engineering		

Objectives

The objectives of this course are to:

- Introduce the fundamental concepts of high voltage engineering and the need for high voltage generation and testing in modern power systems and industrial applications.
- Explain the physical mechanisms of electrical breakdown in gaseous, liquid, and solid dielectric materials under various electric field conditions.
- Familiarize students with high voltage generation techniques, measurement methods, and diagnostic tools used in laboratories and industry.
- Develop an understanding of insulation coordination, overvoltage phenomena, and the role of dielectric materials in ensuring system reliability.
- Enable students to analyse high voltage phenomena such as corona, partial discharge, and insulation failure using theoretical and practical approaches.
- Prepare students to apply high voltage engineering principles in the design, testing, operation, and maintenance of electrical equipment and power systems.

Learning Outcomes

After completing this course, students will be able to:

- Analyse and explain the physical mechanisms governing electrical breakdown and insulation failure in gaseous, liquid, and solid dielectrics under AC, DC, and impulse voltage stresses.
- Evaluate and compare high-voltage generation, measurement, and testing techniques, selecting appropriate methods based on system requirements, standards, and safety considerations.
- Assess insulation performance by interpreting electric field distributions, corona and partial discharge phenomena, and environmental effects, and predict their impact on reliability and life of high-voltage equipment.
- Apply high-voltage engineering principles to practical problems in insulation design, testing, fault diagnosis, and insulation coordination in power and industrial systems.

Contents:

Electric Field Strength (4 lectures)

Concept of electric field and potential distribution in insulating systems. Field computation in simple electrode geometries (plane–plane, sphere–sphere, rod–plane). Field enhancement factors and their influence on breakdown. Methods for electric field control and stress grading in high voltage equipment.

Gaseous Dielectrics (8 lectures)

Ionization processes in gases: primary and secondary ionization mechanisms. Electron avalanches, Townsend theory, and breakdown criteria. Paschen’s law and its applications. Streamer, leader, and spark breakdown mechanisms. Breakdown in uniform and non-uniform fields. Effect of pressure, temperature, humidity, and electrode geometry. Corona discharge: inception, characteristics, power loss, radio interference, and practical significance.

Properties of Liquid and Solid Dielectrics (3 lectures)

Electrical, thermal, and mechanical properties of liquid and solid insulating materials. Polarization mechanisms and dielectric loss. Insulating liquids: mineral oils, synthetic oils, and ester-based fluids. Solid dielectrics: polymers, paper, ceramics, and composite insulation systems. Influence of impurities, moisture, aging, and temperature on dielectric performance.

Breakdown in Liquid and Solid Dielectrics (3 lectures)

Theories of breakdown in liquid dielectrics: electronic, suspended particle, cavitation, and thermal mechanisms. Breakdown processes in solid dielectrics: intrinsic, thermal, electromechanical, and treeing phenomena. Surface flashover and tracking. Comparative discussion of breakdown strength under AC, DC, and impulse voltages.

Generation of High Test Voltages (6 lectures)

Generation of AC high voltages using testing transformers and cascade connections. DC voltage generation using rectifier circuits and voltage multipliers. Impulse voltage and current generation: Marx generator, wave shaping circuits, and standard lightning and switching impulses. Factors affecting voltage waveform and test reliability.

Measurement of High Test Voltages (4 lectures)

Measurement techniques for AC, DC, and impulse voltages. Voltage dividers: resistive, capacitive, and mixed types. Electrostatic voltmeters and sphere gap measurements. Digital recording and measurement of impulse waveforms. Errors, calibration, and uncertainty considerations.

Non-destructive High Voltage Testing and Quality Control (4 lectures)

Principles of non-destructive testing of insulation systems. Partial discharge detection and measurement techniques. Dielectric loss (tan δ) measurement. High voltage tests on cables, transformers, and rotating machines. Role of high voltage testing in quality control, condition monitoring, and predictive maintenance.

Insulation Coordination and Over Voltages in Power Systems (2 lectures)

Concept of insulation coordination and protective margins. Classification of overvoltages: lightning, switching, and temporary overvoltages. Protective devices such as surge arresters and shielding methods. Basic insulation level (BIL) and coordination in power system design.

Introduction National and International standards such as IEC-60060-1, 60-2, etc. (2 lecture)

Overview of national and international standards related to high voltage testing and insulation coordination. Introduction to IEC 60060-1 and IEC 60060-2 standards. Standard test voltages, procedures, safety requirements, and acceptance criteria.

Recent trends and developments (2 lectures)

Advances in insulating materials and eco-friendly dielectrics. High voltage DC (HVDC) insulation challenges. Online condition monitoring and diagnostics using AI and signal processing. Emerging testing techniques and future directions in high voltage engineering.

Textbook

1. High Voltage Engineering by M. S. Naidu, Kamaraju, TMH, 2020 6th Ed.
2. High Voltage and Electrical Insulation Engineering, By R. Arora, W. Mosch, Wiley-IEEE Press, 2022, Ed.2.

Reference Book:

1. High Voltage Engineering by Kuffel, E., by Newnes 2009.
2. NPTEL High Voltage Engineering, Prof. Ravindra Arora, https://nptel.ac.in/courses/108104048
3. Fundamentals of High-Voltage Engineering, By R. Arora, B. S. Rajpurohit, Wiley-India, 2019.
4. Relevant standards by instructor

Title	**Control Techniques in Power Engineering**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [E]	3-0-0 [3]
Offered for	M.Tech., B.Tech., Ph.D.	Type	E
Prerequisite	Linear control theory		

Objectives

The instructor will:

1. Help students fit together their complete control theory background to tackle practical design of a control loops for power converters.

Learning Outcomes

The students are expected to have the ability to:

- Design control loops for DC-DC, DC-AC a, AC-DC and motor drive application
- Derive average model of a power converter system and design the closed loop control for it.
- Perform the stability analysis on a closed loop power converter system

Contents

Module I: Introduction to basic concepts

- **Basic of feedback control (5 Lectures)**

Open-Loop systems; the necessity of Feedback Control; Notions of time constants; Performance of a feedback Control system; Transfer Function: The Laplace Transform, Excitation and Response Signals; Transient Response and roots; S-Plane and Transient Response; Combining Transfer Function with Bode plots; Review of Linear control theory.

Case Study: Derive the Transfer function of a buck converter and plot its poles and zero in S-Plane

- **Modelling of Power Electronics Converters (5 Lectures)**

Introduction to converter Modelling; Switched Model; Classical Averaged Model; Generalised Average Model; Reduced-order averaged model; Zeros in Right Half Plane

Case study: Visualise the Right half plane zero in Boost converter using average model.

Module II: Control of Power Electronics system

- **Control Approaches For DC-DC power Converter (11 Lectures)**:

Small signal Modelling: State space averaging; PWM switch Model: Voltage mode case, current mode case, Parasitic elements Effects, Borderline conduction; ***Other Averaged Models***: Ridley Models, Small-Signal current Mode Models, CoPEC models, Ben-Yaakov Models.

Control Methods: Voltage Mode control, Current Mode control: Peak current mode control, average current mode control, Hysteresis controls, Voltage feed-forward control.

Feedback and control Loops: Observation Points; Stability Criteria; Phase Margin and Transient Response; Choosing the Crossover Frequency; Shaping the compensation Loop; K-Factor approach, Pole-Zero Cancellation, compensating converter with zero in RHP.

Compensation using: Operational Amplifier, Operational Transconductance Amplifier, TL431, Optocoupler, shunt regulator; Small-signal response with Circuit simulator.

Case Study: Simulation and Practical Design of an isolated DC-DC converter, e.g., Flyback converter.

- **Control Approaches for DC-AC and AC-DC converters (10 Lectures):**

Control of DC-AC converter:

Introductory issues, Control in Rotating dq Frame; Resonant Controllers***:*** Necessity of Resonant control, basic of Proportional Resonant control; dq Control of a PWM 3-Phase grid tied inverter: design of inner current loop, design of outer voltage loop.

Case Study: Example of a grid connected single phase DC-AC converter

Control of AC-DC converter: Average current controlled rectifier; Voltage regulated UPF rectifier; Voltage regulated UPF rectifier with voltage feed-forward; ***Control of PFC converter:*** Designing the inner average-current -control loop, designing the outer voltage loop, voltage feed-forward controller, example of a single-phase PFC system.

Case Study: Design a current and voltage control loop of a single-phase boost PFC converter.

- **Control for Motor Drive system (8 Lectures)**

Control objective, Cascaded Control Structure; Steps in Designing the Feedback Controller; System Representation for Small-signal analysis; Controller Design; Role of Feedforward; Effects of Limits; Anit-windup integration.

Case Study: Design of a Torques Control Loop for a Permanent Magnet DC motor.

Textbook

- IEEE Papers and industry application notes

Reference Books:

- Ned Mohan, Siddharth Raju, Power Electronics, A First Course: Simulations and Laboratory Implementations 2nd Edition., 2022.
- Katsuhiko Ogata, Modern control engineering, 2009.

Title	**Deep Learning (700)**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [E]	3–0–0 [3]
Offered for	M.Tech. 1st Year, Ph.D. 1st Year	Type	E
Prerequisite	Machine Learning	Antirequisite	Deep Learning (400) - CSL4xx

Objectives

1. Provide technical details about various recent algorithms and software platforms related to Machine Learning with specific focus on Deep Learning.

Learning Outcomes

Students are expected to have the ability to:

1. Design and program efficient algorithms related to recent machine learning techniques, train models, conduct experiments, and develop real-world DL-based applications and products

Contents

Fractal 1: Foundations of Deep Learning

Deep Networks: CNN, RNN, LSTM, Attention layers, Applications (8 lectures)

Techniques to improve deep networks: DNN Optimization, Regularization, AutoML (6 lectures)

Fractal 2: Representation Learning

Representation Learning: Unsupervised pre-training, transfer learning, and domain adaptation, distributed representation, discovering underlying causes (8 lectures)

Auto-DL: Neural architecture search, network compression, graph neural networks (6 lectures)

Fractal 3: Generative Models

Probabilistic Generative Models: DBN, RBM (3 lectures)

Deep Generative Models: Encoder-Decoder, Variational Autoencoder, Generative Adversarial Network (GAN), Deep Convolutional GAN, Variants and Applications of GANs (11 lectures)

Text Book

1. Goodfellow,I., Bengio.,Y., and Courville,A., (2016), Deep Learning, The MIT Press .

Reference Book

1. Charniak, E. (2019), Introduction to deep learning, The MIT Press.
2. Research literature.

Self Learning Material

1. https://www.deeplearningbook.org/

Title	**Machine Learning (700)**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [E]	3–0–0 [3]
Offered for	M.Tech. (CSE, AI, DCS), PhD	Type	E
Prerequisite	Introduction to Computer Sc., Probability, Statistics and Stochastic Processes, Linear Algebra	Antirequisite	IML, PRML

Objectives

1. To understand various key paradigms for machine learning approaches
2. To familiarize with the mathematical and statistical techniques used in machine learning.
3. To understand and differentiate among various machine learning techniques.

Learning Outcomes

The students are expected to have the ability to:

1. To formulate a machine learning problem
2. Select an appropriate pattern analysis tool for analyzing data in a given feature space.
3. Apply pattern recognition and machine learning techniques such as classification and feature selection to practical applications and detect patterns in the data.

Contents

Fractal I: Supervised Learning

Introduction: Definitions, Datasets for Machine Learning, Different Paradigms of Machine Learning, Data Normalization, Hypothesis Evaluation, VC-Dimensions and Distribution, Bias-Variance Tradeoff, Regression (Linear) (7 Lectures)
Bayes Decision Theory: Bayes decision rule, Minimum error rate classification, Normal density and discriminant functions (5 Lectures)
Parameter Estimation: Maximum Likelihood and Bayesian Parameter Estimation (2 Lectures)

Fractal II: Unsupervised Learning

Discriminative Methods: Distance-based methods, Linear Discriminant Functions, Decision Tree, Random Decision Forest and Boosting (6 Lectures)
Feature Selection and Dimensionality Reduction: PCA, LDA, ICA, SFFS, SBFS (4 Lectures)
Clustering: k-means clustering, Gaussian Mixture Modeling, EM-algorithm (4 Lectures)

Fractal III: Kernels and Neural Networks

Kernel Machines: Kernel Tricks, SVMs (primal and dual forms), K-SVR, K-PCA (6 Lectures)
Artificial Neural Networks: MLP, Backprop, and RBF-Net (4 Lectures)
Foundations of Deep Learning: DNN, CNN, Autoencoders (4 lectures)

Text Book

1. Shalev-Shwartz,S., Ben-David,S., (2014), Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press
2. R. O. Duda, P. E. Hart, D. G. Stork (2000), Pattern Classification, Wiley-Blackwell, 2nd Edition.

Reference Book

1. Mitchell Tom (1997). Machine Learning, Tata McGraw-Hill
2. C. M. BISHOP (2006), Pattern Recognition and Machine Learning, Springer-Verlag New York, 1st Edition.

Self-Learning Material

1. Department of Computer Science, Stanford University, https://see.stanford.edu/Course/CS229

Title	Introduction to Smart Grid	Number	EE7XX0
Department	Electrical Engineering	L-T-P [E]	[3-0-0] [3]
Offered for	B.Tech./M.Tech/Ph.D.	Type	E
Prerequisite	Power Engineering (for B.Tech. students)		

Objectives
The Instructor will:
Provide concepts and topics that are relevant to smart grid technologies to facilitate exploring research opportunities

Learning Outcomes
The students are expected to have the ability to:
Understand the basic concepts of smart grid development and the critical technologies that underpin such development, their basic principles, physical constraints, and technological potentials

Contents

Smart Grid Basics: Evolution of Electric Power Grid and Smart Grid, Objectives, main features and challenges of smart grid (5 lectures)
Energy Resources: Centralized vs. distributed generation (1 lecture); renewable energy: solar, wind, hydropower, biomass, geothermal, ocean wave; benefit, costs, and policies of renewable energy (5 lectures); renewable sources integration overcoming intermittence; storage systems technology (4 lectures)
Plug-in Electric Vehicle (PEV): History of EV; PEV challenges and potential solutions (1 lecture); EV and electric power grid; PEV charging infrastructure, challenges and solutions (4 lectures); PEV as an energy storage device and an energy source (V2G) (2 lectures)
Demand-side management: Load profile of the power grid; market pricing (3 lectures); peak shaving and valley filling; load forecasting (4 lectures); regulations and policies (3 lectures)
Monitoring and Protection: Wide-area monitoring system (WAMS), SCADA and PMU (4 lectures); advanced metering infrastructure (AMI); smart metering (3 lectures); communication infrastructure and technologies (3 lectures)

Textbook
1. Bollean,M.H.J., Hasan,F., (2011), Integration of Distributed Generation in the Power Systems, Willey-IEEE India Press
2. Ehsani,M., Gao,Y., Gay,S.E., Emadi,A., (2005), Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, CRC Press
3. Bansal,R., (2019), Power System Protection in Smart Grid Environment, CRC Press

Reference Books;
The Smart Grid: An Introduction,
http://www.oe.energy.gov/SmartGridIntroduction.htm, Department of Energy, 2008.

Title	Renewable Energy Systems	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [E]	[3-0-0] [3]
Offered for	B.Tech.	Type	E
Prerequisite			

Objectives
The Instructor will:
Provide exposure to operation of various non-conventional energy sources, their characteristics, and their interface with grid

Learning Outcomes
The students are expected to have the ability to:
Design and develop standalone and grid connected renewable energy systems

Contents
Solar PV: Solar PV characteristics, cell, module, array, series parallel combination, partial shading, MPPT (3 lectures), grid synchronization using various converter topologies (3 lectures)
Solar Thermal: Principle of operation, thermal efficiency, concentrators-architecture, applications (4 lectures)
Wind Energy Systems: Principle of operation, types of wind turbines, Cp-λ characteristics, Betz limit, MPPT, onshore and offshore wind farms (4 lectures), types of wind generators-operation and control of various types of generators (6 lectures)
Hydro Power Generation: Hydro systems, hydro resources, types of hydro turbine, small, mini and micro hydro systems, pumped storage (6 lectures)
Fuel Cells: Types, principle of operation, V-I characteristics, applications (4 lectures)
Other Renewable Energy Sources: Introduction to geothermal, ocean, biomass energy generation (6 lectures)
Energy Storage Systems: Introduction to various mechanical, chemical, electro-chemical, and electrical storage systems and their applications (6 lectures)

Textbook

- Bollean,M.H.J., Hasan,F., (2011), Integration of Distributed Generation in the Power Systems, Willey-IEEE India Press
- Masters,G.M., (2004), Renewable and Efficient Electric Power Systems, John Wiley & Sons, Inc.

Reference Book:

- Bhadra,S.N., Kastha,D., Banerjee, S., (2005), Wind Electrical Systems, Oxford Univ. Press

Title	Power System Protection	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [E]	[3-0-0] [3]
Offered for	B.Tech.	Type	E
Prerequisite	Power System Analysis and Stability		

Objectives

The Instructor will provide knowledge of:

1. Various protection schemes and their applications in power industry
2. Relay coordination, instrument transformers
3. Numerical protection schemes based on signal processing techniques

Learning Outcomes

The students are expected to have the ability to:

1. Design/propose protection schemes for various power system components based on digital signal processing
2. Design relay coordination systems in distribution and transmission

Contents

Overview of Power System Protection: Architecture of protection system, evolution of relays, zones of protections, concept of primary and back-up protection (2 lectures)

Overcurrent Protection: Principles of fuse and overcurrent protection and application to feeder and motor protection, relay coordination in distribution system (6 lectures)

Distance Protection: Principles of distance relaying (2 lectures) and application to transmission system protection, relay coordination (5 lectures)

Differential Protection: Principles of differential protection (2 lectures) and application to transformer, bus bar and generator armature winding protection (5 lectures)

Introduction to Digital Relaying: Sampling, concept of moving window, signal conditioning, signal processing (4 lectures)

Instrument Transformer: Current and voltage transformers in power system protection (6 lectures)

Circuit breakers: Arc initiation and quenching, oil circuit breakers, air blast circuit breakers vacuum circuit breakers, SF6 circuit breakers (5 lectures), current chopping, reverse recovery voltage (3 lectures)

Lightning arresters: Principle of operation and types (2 lectures)

Textbook

1. Singh, L.P., (2017), Digital Protection: Protective Relaying from Electromechanical to Microprocessor, 2nd Edition, New Age International Publications
2. Ram,B., Vishwakarma,D.N., (2017), Power System Protection and Switchgear, 2nd Edition, Tata McGraw Hill Publications.
3. Phadke,A.G., Thorp,J.S., (2009), Computer relaying for Power System, 2nd Edition, John Wiley & Sons Ltd. Publications

Reference Book

Soman,S.A., Power System Protection, NPTEL Course Material, Department of Electrical Engineering, Indian Institute of Technology Bombay,
https://nptel.ac.in/courses/108/101/108101039/

Title	Introduction to Cyber Physical Systems	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [E]	[3-0-0] [3]
Offered for	M.Tech. Cyber Physical Systems	Type	E
Prerequisite	Differential Equations, Basics of Microprocessors		

Objectives

The Instructor will:
introduce modeling of CPS
introduce ability to analyze and simulate CPS systems

Learning Outcomes

The students are expected to have the ability to:
apply modeling and associated tools for Hybrid system
to analyze CPS by with holistic models of cyber and physical components.

Contents

Motivation and examples of CPS e.g. Energy, Medical and Transportation cyber physical systems; Key design drivers and quality attributes of CPS. Attributes of high confidence CPS; (8 hours)

Continuous systems modeling; Discrete time system modeling; Finite state machine; Extended state machines; Hybrid system modeling; Classes of Hybrid Systems. (17 Hours)

Analysis and Verification:

Basic concepts of embedded systems; Embedded Processors; Input-outputs; Invariants and Temporal Logic; Linear Temporal Logic; Equivalence and Refinement; Development of models from specifications; Rechability analysis and Model Checking (17 Hours)

Text Books

- R. Rajkumar, D. de. Niz and M. Klein, (2017), Cyber Physical Systems, Addision-Wesely.
- E.A.Lee and S A Shesia, (2018), Embedded system Design: A Cyber-Physical Approach, Second Edition, MIT Press.
- A.Platzer, (2017), Logical Foundations of Cyber Physical Systems, Springer.

Reference book

- Basics of Differential equations and basics of Microprocessors from any standard textbook.

Title	HVDC and FACTS	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [E]	[3-0-0] [3]
Offered for	B.Tech./M.Tech./Ph.D.	Type	E
Prerequisite	Power System Analysis and Stability, Power Electronics (for B.Tech students)		

Objectives

The Instructor will:

1. Present the need and operational aspects of HVDC transmission systems along with their associated converters and their control
2. Provide concepts of series and shunt compensation to enhance the performance of transmission lines and stability of Power System using FACTS devices

Learning Outcomes

The students are expected to have the ability to:

1. Develop converters and their control methods in HVDC transmission systems
2. Develop converter topologies and their control methods for FACTS devices

Contents

Introduction: Introduction of DC power transmission technology, comparison of AC and DC transmission, advantages, limitations and types of HVDC transmission systems (3 lectures)

LCC HVDC systems: Ignition angle, commutation overlap, relation between AC and DC quantities (4 lectures)

Control of HVDC systems: CIA, CC, CEA characteristics, current limits (3 lectures)

Harmonics and filters: AC and DC side harmonics (3 lectures)

Interaction with AC system: Effective Short Circuit Ratio, dynamic overvoltage, voltage stability, harmonic resonance (2 lectures)

Introduction to VSC HVDC systems: Introduction to VSC HVDC systems, voltage analysis, active and reactive power flow, control of VSC HVDC systems (3 lectures)

FACTS devices: Objectives of compensation, types of compensation (2 lectures)

Shunt compensators: TCR, TSR, TSC, SVC and STATCOM - principle of operation, modeling, and control (6 lectures)

Series compensation: SSSC, TSSC, TCSC, and TCSR - principle of operation, modeling, and control (6 lectures)

Voltage and phase angle regulators: Thyristor controlled voltage and phase angle regulators - principle of operation, modeling, and control (4 lectures)

Power flow controllers UPFC and IPFC - principle of operation, modeling, and control (6 lectures)

Textbook

1. Padiyar,K.R., (2017), HVDC Power Transmission Systems, 3rd Edition, New Age Publishers
2. Hingorani,L.G., Gyugyi,L., (2000), Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, IEEE Press

Reference book:

1. Singh,S.N., High Voltage DC Transmission, NPTEL Course Material, Department of Electrical Engineering, Indian Institute of Technology Kanpur, https://nptel.ac.in/courses/108/104/108104013/
2. Bhattacharya,A., Facts Devices, NPTEL Course Material, Department of Electrical and Electronics Engineering, IIT Roorkee, https://nptel.ac.in/courses/108/107/108107114/