POWER SYSTEM OPERATION AND CONTROL

Course Code: PSM-201

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1. **Course Pre-requisites:**
    1. Electric Power systems
    2. Control system

2. **Course Learning Objectives:**

    A "Power System Operation and Control" course typically aims to teach students how to analyze and manage the flow of electrical power within a grid, including understanding real and reactive power control, load flow studies, automatic generation control, unit commitment, economic dispatch, stability analysis, and various methods for maintaining system reliability under varying load conditions, all with the objective of operating the system efficiently and economically.

3. **Course Name: POWER SYSTEM OPERATION AND CONTROL**
    Course Code: PSM-201
    Hours per Week: 4
    Credits: 4

    Course Contents:

Module	Topics	40L
1.	**Optimal Generation Scheduling:** Power flow scheduling using economic load dispatch, power flow scheduling using Lagrange multiplier method, penalty factor, scheduling with network losses, hydrothermal coordination with and without losses, cascaded and pump storage plant scheduling, unit commitment, unit commitment solution methods, introduction to optimal power flow solution using Newton Raphson method	12
2.	**Automatic Generation Control:** Types of alternator exciters, automatic voltage regulators for generator excitation control, static and dynamic performance of AVR loop, automatic load frequency control, primary automatic load frequency control loop, secondary automatic load frequency control loop, extension of automatic load frequency control loop to multi area systems, tie line power flow model.	12
3.	**Power System Security:** Security analysis, security assessment, contingency analysis, algorithm to determine system security following contingency analysis procedure, security assessment using ac power flow model, security analysis using concept of performance index.	06
4.	**State Estimation and load forecasting**: Methods of state estimation – least square and weighted least square estimation, bad data detection and suppression of bad data, load forecasting, load forecasting techniques – methods of extrapolation and correlation, estimation of average and trend terms of deterministic part of load limitation of the method, prediction of deterministic load, generalized load modeling, estimation of periodic components, estimation of stochastic part of load – time series approach.	10

4. Text Books:

T1: Power System Analysis Operation and Control, Abhijit Chakrabarti and Sunita Halder, PHI**.**

T2: Power Generation Operation and Control, Allen J. Wood, Bruce F. Woolenburg, Wiley.

5. References:

R1: Power System Operation and Control" Author: S.Sivanagaraju and S.Satyanarayana. Pearson

6. Course Outcomes:

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	Understand the concept of Optimal Power System Operation under various operating constraints	Analyze, Evaluating	Understand, Remember
CO2	Solve unit commitment and economic dispatch problems.	Analyze, Evaluating	Understand, Apply, Evaluating
CO3	Provide the knowledge of Hydrothermal scheduling, reactive power control.	Understand, Analyze	Understand, Apply
CO4	Acquire the knowledge of Turbine Speed Governing System.	Analyze, Evaluating	Understand, Apply, Analyze
CO5	Understand the concept of security assessment and contingency analysis	Understand, Remember	Evaluate
CO6	Understand the concept of State Estimation and load forecasting.	Understand, Remember	Understand, Apply, Analyze

7. Mapping of course outcomes to module/course content:

Module	CO1	CO2	CO3	CO4	CO5	CO6
1	3	-	2	1	-	-
2	1	3	-	3	-	-
3	-	-	-	2	3	-
4	-	-	-	-	-	3

8. Mapping of CO to PO:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	1	1	-	2	2	-	-	-	1
CO2	3	3	1	1	-	2	1	-	-	-	1
CO3	3	3	1	1	-	1	2	-	-	-	1
CO4	3	3	1	1	-	2	2	-	-	-	1
CO5	3	3	1	1	-	2	1	-	-	-	1
CO6	3	3	1	1	-	2	2	-	-	-	1

9. Mapping to PSO:

	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2
CO2	3	1	1	1
CO3	3	2	2	1
CO4	3	-	2	1
CO5	3	2	1	2
CO6	3	2	3	2

POWER SYSTEM INSTRUMENTATION

Course Code: PSM-202

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1. **Course Pre-requisites:**
   a. Power Electronics
   b. Electric Power Systems
   c. Electrical Measurements

2. **Course Learning Objectives:**
   The course is designed with a comprehensive understanding of advanced measurement and monitoring techniques that are essential for the efficient operation, control, and protection of modern power systems. An important objective of the course is to familiarize students with modern data acquisition and processing methods. The course also focuses on instrumentation as applied to protection and fault analysis in power systems. Further, the course is oriented toward the future of power system monitoring and control by integrating concepts of digital and intelligent instrumentation which understand the vulnerabilities and challenges associated with digital transformation in power systems. By engaging with recent advancements, case studies, and real-world applications, prepared to contribute innovative solutions to emerging challenges in renewable energy integration, smart grid development, and big data analytics for power systems. The overarching objective is to empower learners with the knowledge and skills necessary to design, implement, and critically evaluate instrumentation systems that support a resilient, intelligent, and sustainable power infrastructure.

3. **Course Name: POWER SYSTEM INSTRUMENTATION**
   Course Code: PSM-202
   Hours per Week: 4
   Credits: 4

   Course Contents:

Module	Topics	40L
1.	**Fundamentals of Power System Instrumentation**-Role of instrumentation in power systems, Measurement principles: voltage, current, frequency, power, energy, and phase angle, Sensors and transducers: CTs, PTs, Hall-effect sensors, fiber-optic sensors, Signal conditioning, isolation, and noise reduction techniques.	08
2.	**Data Acquisition and Processing** - Data acquisition systems (DAS) architecture, Sampling, quantization, and digitization, SCADA systems and their application in power system monitoring, Phasor Measurement Units (PMUs) and Wide Area Measurement Systems (WAMS).	08
3.	**Instrumentation for Protection and Control** - Instrumentation in protective relaying (over-current, distance, differential, and numerical relays), Fault detection, recording, and disturbance analysis, Microprocessor-based protection systems, Condition monitoring of transformers, circuit breakers, and transmission lines.	08
4.	**Power Quality and Stability Measurements** - Power quality indices and monitoring techniques, Measurement of harmonics, flicker, voltage sags, swells, and transients, Dynamic monitoring of frequency, rotor angle, and system oscillations, Real-time monitoring of renewable energy integration and stability issues.	08
5.	**Intelligent and Digital Instrumentation** - Digital instrumentation systems and embedded controllers, AI and ML-based fault detection and predictive maintenance, Smart grid instrumentation, IoT-based sensors, and cloud	08

	monitoring, Cyber security in power system instrumentation.	

4. Text Books:

T1. A. G. Phadke and J. S. Thorp, Synchronized Phasor Measurements and Their Applications, Springer.

T2. H. M. Bernstein and S. A. MacArthur, Power System Instrumentation and Measurement, Wiley.

T3. Kalsi H. S., Electronic Instrumentation, Tata McGraw-Hill.

5. References:

R1. Murty P. S. R., Power System Protection and Switchgear, PHI.

R2. Reza Arghandeh & Yuxun Zhou, Big Data Application in Power Systems, Elsevier.

R3. IEEE Standards on Power Quality Measurement and Instrumentation.

6. Course Outcomes:

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	To impart knowledge on advanced instrumentation techniques used in modern power systems.	Analyze, Identify	Understand, Remember
CO2	To understand transducers, sensors, and data acquisition systems relevant to electrical measurements.	Identify, Select	Understand, Apply, Analyze
CO3	To study protection-oriented instrumentation and monitoring systems in power systems.	Identify, Select	Understand, Apply
CO4	To expose students to intelligent instrumentation and digital techniques for real-time monitoring.	Analyze	Understand, Apply, Analyze
CO5	To analyze power quality, stability, and system performance using advanced instrumentation tools.	Identify	Analyze

7. Mapping of course outcomes to module/course content:

Module	CO1	CO2	CO3	CO4	CO5
1	3	-	-	-	-
2	2	3	-	-	-
3	2	-	3	-	-
4	3	-	3	-	-
5	3	-	-	3	-

8. Mapping of CO to PO:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	-	-	2	-	-	-	-	-	1
CO2	3	3	3	2	2	-	-	-	2	-	1
CO3	3	3	3	3	2	2	-	3	2	-	1
CO4	3	3	-	3	2	1	1	-	-	-	1
CO5	3	3	3	3	2	1	1	2	3	2	1

9. Mapping to PSO:

	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	1
CO2	3	3	1	2
CO3	3	2	1	2
CO4	3	2	1	1
CO5	3	2	1	2

ADVANCED POWER SYSTEM PROTECTION

Course Code: PSM-203

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1. **Course Pre-requisites:**
   1. Power system-I
   2. Power system-II
   3. Electrical & Electronics Measurement

2. **Course Learning Objectives:**
   "Advanced Power System Protection" course typically aims to teach students to have deep understanding of complex protection schemes, including the analysis of different fault types, selection and application of advanced protective relays, coordination of protection devices and the ability to design and implement protection schemes for various power system components like transmission lines, transformer, generators, and bus bars.

3. **Course Name: ADVANCED POWER SYSTEM PROTECTION**
   Course Code: PSM-203
   Hours per Week: 4
   Credits: 4

   Course Contents:

Module	Topics	40L
1.	**Fundamentals of Power System Protection:** Protective relays: principles, requirements, and types; Relay characteristics and operating equation; Protective CTs and PTs; Phase and amplitude comparators, electromagnetic relay classification; Plug Setting Multiplier, Time Multiplier Setting, Universal Torque Equation; Non-directional, directional, distance, and differential relays	05
2.	**Alternator Protection:** Stator fault protection (phase-to-phase, phase-to-ground, inter-turn faults); Balanced & restricted earth fault protection; Unbalanced loading, prime mover failure, overvoltage, overcurrent protection; Rotor protection techniques; Modern approaches in generator protection systems	07
3.	**Transformer Protection:** Overcurrent and unrestricted earth fault protection; CT connections for transformer protection; Harmonic restraint and inrush current discrimination; Restricted earth fault protection; Frame leakage protection; Recent trends in digital transformer differential protection	05
4.	**Busbar, Feeder & Transmission Line Protection:** Busbar protection: circulating current and frame leakage schemes; Feeder protection: time-graded, differential protection; Transmission line distance protection: impedance, reactance, mho relays; High-speed relays and relay coordination; Pilot relaying: wire pilot, carrier current protection; Wide-area protection systems.	05
5.	**Static, Digital and Numerical Relays:** Static relay concepts: overcurrent, time overcurrent, instantaneous, directional, differential, distance; Comparators and associated circuits; System switching & transient effects; Digital relays: hardware, protection schemes, algorithms; Microprocessor and microcontroller-based relays; Numerical relays and IEC 61850 communication.	10

6.	**Protection of Special Equipment:** High-voltage capacitor bank protection (inrush, overcurrent, overvoltage, differential schemes); Large motor protection (stalling, negative sequence effects, thermal overloads); Protection of FACTS devices and HVDC systems; Renewable energy system protection (wind & solar integration challenges)	08

4. Text Books:

T1: A. Chakrabarti,M.L. Soni, P. V. Gupta, U. S. Bhatnagar "A text book on Power System Engineering", Dhanpat Rai and Co.

T2: Paithankar.Y.G and Bhide.S.R, "Fundamentals of Power System Protection", Prentice-Hall of India.

5. References:

R1: Badri Ram and Vishwakarma.D.N, "Power System Protection and Switchgear", Tata McGraw- Hill Publishing Company, 2002.

R2: Arun K. Phadke, James. S. Thorp, "Computer relaying for Power system", John Wiley and sons, New York, 1998.

6. Course Outcomes:

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	Explain the principles, operating equations, and characteristics of various protective relays, instrument transformers, and comparator types used in power system protection.	Explain	Understand
CO2	Analyze and apply suitable protection schemes for alternators, including stator, rotor, and system-related faults, as well as overcurrent and earth fault conditions.	Analyze and Apply	Apply, Analyze
CO3	Design and evaluate transformer protection methods, incorporating CT connections, harmonic restraint, frame leakage, and restricted earth fault schemes.	Design and evaluate	Understand
CO4	Select and implement protection strategies for busbars, feeders, and transmission lines using distance relays, pilot relaying schemes, and appropriate relay settings.	Select and implement	Apply
CO5	Differentiate between electromagnetic, static, digital, and numerical relays, and assess their components, algorithms, and performance under system disturbances and transients.	Differentiate, Assess	Understand
CO6	Develop suitable protection systems for special equipment such as high-voltage capacitor banks, large motors, FACTS devices, and renewable energy systems.	Develop	Analysis

7. **Mapping of course outcomes to module/course content:**

Module	CO1	CO2	CO3	CO4	CO5	CO6
1	3	2	-	-	-	-
2	-	3	-	-	-	-
3	-	-	3	-	-	-
4	-	-	2	3	-	-
5	-	-	2	2	3	-
6	-	-	-	-	-	3

8. **Mapping of CO to PO:**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	2	-	-	1	1	-	-	-	1
CO2	3	3	2	2	1	2	1	-	-	-	1
CO3	2	3	3	3	2	2	3	-	-	-	1
CO4	3	2	2	3	1	1	1	-	-	-	1
CO5	3	3	3	1	2	3	2	-	-	-	1
CO6	2	2	3	2	3	2	2	-	-	-	1

9. **Mapping to PSO:**

	PSO1	PSO2	PSO3	PSO4
CO1	2	3	1	1
CO2	3	2	1	1
CO3	3	2	1	2
CO4	2	3	2	1
CO5	3	2	1	2
CO6	3	3	2	1

POWER SYSTEM TRANSIENTS
Course Code: PSM-204

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1. Course Prerequisite:
Network Theory
Power System-I
Power System-II

2. Course Learning Objectives:
The switching and lightning transient voltages that power system components may carry over and beyond the power frequency voltage are covered in detail in this course. This course describes how to model a transmission line in order to calculate such voltages. Also, insulation design in these kinds of situations is covered here.

3. Course Content:
Course Name: Power System Transients
Course Code: PSM-204
Hours per Week: 4
Credits: 4

Module	Topics	40 L
1.	**Introduction and Survey:** Source of transients, various types of power systems transients, effect of transients on power systems, importance of study of transients for insulation design	4
2.	**Travelling Waves on Transmission Line:** Introduction, Circuit with Distributed constats, The wave equation, Reflection and Refraction of Travelling Waves, Behaviour of Travelling waves at Line Termination, Lattice Diagrams, Attenuation and Distortion of Travelling Waves, Switching operations involving Transmission Lines, Multi-conductor Systems and Multi-velocity Waves, Switching Surges on an integrated Systems and Problem on related Topics.	10
3.	**Lightning Transients:** Introduction, Scope of Lightning Problem, The Physical phenomena of lightning phenomenon, charge formation in the clouds, rate of charging of thunder clouds, mechanisms of lighting strokes, Computation of a Specific lightning Events, Induced Lightning Surges, Protection afforded by ground wires, Tower footing resistance. Interaction between lightning and power system: Mathematical model for lightning	8
4.	**Computation of Transients:** Introduction: principle of digital computation of transients, features and capabilities of electromagnetic transients program; steady state and time step solution modules: basic solution methods; case studies on simulation various types of transients using PSCAD/ EMTP	5
5.	**Protection of Systems and Equipment against Transient Over-voltages:** Introduction, Protection of transmission line against lightning, Lightning Shielding of Substation, Surges Suppressors and Lightning arresters, Application of Surge Arresters, Surge Capacitors and Surge Reactors, Surge Protection of Rotating Machines, Transient Voltages	10

Module	Topics	40 L
	and Grounding Practices, Protection of Control Circuits, Surge Protection Scheme for industrial Drive System, Problems	
6.	**Insulation Coordination:** Some Basic Idea about Insulation Coordination, The Strength of Insulation, The Hierarchy of Insulation Coordination, Test Voltage Waveforms and Transient Ratings, Determination and Statistical Approaches to Insulation Coordination.	3

4. Text Book:

T1: Electrical Transients in Power Systems by Allan Greenwood, Wiley.

T2: High Voltage Engineering by M.S. Naidu and V. Kamaraju, Tata McGraw Hill, 2nd edition, 2000.

T3: Extra High Voltage AC Transmission Engineering by R.D. Begamudre, New Age International.

5. Reference Books:

R1: Electromagnetic Transients in Power System by Pritindra Chowdhari, John Wiley and Sons Inc., Second Edition 2009.

R2: Power System Transients- A Statistical Approach by C.S. Indulkar, D.P. Kothari and K. Ramalingam.

R3: Handbook of Power System Engineering by Y. Hase, Willey India 2012.

6. Course Outcomes:

Course Outcomes	**Details/Statement**	**Action Verb**	**Knowledge Level**
CO1	Analyze the sources, types, and effects of power system transients, and their role in insulation design	Analyze	Analyzing
CO2	Model and compute travelling wave phenomena on transmission lines, including reflection, refraction, attenuation, and distortion	Mode, Compute	Applying and Analysing
CO3	Evaluate lightning transients, including physical mechanisms, mathematical modelling, and protective measures	Evaluate	Evaluating
CO4	Simulate and interpret transient phenomena using computational tools such as EMTP for various switching and lightning scenarios	Simulate, Interpret	Applying and Analysing
CO5	Design and assess protection schemes for systems and equipment against transient over-voltages, and apply insulation coordination principles	Design, Assess and Apply	Applying, Evaluating and Creating

7. **Mapping of course outcomes to module / course content:**

Module	CO1	CO2	CO3	CO4	CO5
1	3	1	1	-	2
2	1	3	-	2	1
3	1	-	3	2	2
4	-	2	2	3	-
5	1	-	2	1	3
6	2	-	-	-	3

8. **Mapping of the Course outcomes to Program Outcomes:**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	2	2	1	1	-	-	1	-	2
CO2	3	3	2	2	3	-	-	1	-	-	2
CO3	3	3	2	3	2	2	1	1	1	-	2
CO4	3	3	2	3	3	-	-	1	-	-	2
CO5	3	3	3	2	2	2	1	1	1	1	2

9. **Mapping to PSO:**

	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	2
CO2	3	2	2	1
CO3	3	2	2	2
CO4	2	3	2	1
CO5	3	2	2	2

FLEXIBLE AC TRANSMISSION SYSTEM

Course Code: PSM-205

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1. **Course Pre-requisites:**
    1. Electric Power Systems
    2. Control System
    3. Power Electronics

2. **Course Learning Objectives:**
   Typically aim to equip students with a comprehensive understanding of Flexible AC Transmission Systems (FACTS) devices, enabling them to analyze, design, and apply these devices to improve power transmission stability, control power flow, and optimize voltage regulation within electrical grids.

3. **Course Name: FLEXIBLE AC TRANSMISSION SYSTEM**
   Course Code: PSM-205
   Hours per Week: 4
   Credits: 4

   Course Contents:

Module	Topics	40L
1.	**Concepts of Flexible A C Transmission Systems:** Transmission line Interconnections, Power flow in parallel lines, Mesh systems, Stability considerations, Relative importance of controllable parameters, Basic types of FACTS controllers, Shunt controllers, Series controllers, Combined shunt and series controllers, Benefits of FACTS	6
2.	**Static shunt compensators:** Objectives of Shunt Compensation, Midpoint Voltage Regulation for Line Segmentation, End of Line Voltage Support to Prevent Voltage Instability, Improvement of Transient Stability, Power Oscillation Damping, Methods of Controllable VAR Generation, Variable Impedance Type Static VAR Generators, Switching Converter Type VAR Generators, Hybrid VAR Generators, SVC and STATCOM, Transient Stability Enhancement and Power Oscillation Damping, Comparison Between STATCOM and SVC, V- I, V-Q Characteristics, Response Time.	12
3.	**Static series compensators:** Objectives of series compensation, voltage stability, improvement of transient stability, power oscillation damping, sub-synchronous oscillation damping, variable impedance type series compensators, GTO thyristor controlled type series capacitor (GCSC), thyristor switched series capacitor (TSSC), thyristor-controlled series capacitor (TCSC), basic operating control schemes for GCSC, TSSC, and TCSC, switching converter type series compensators, the static synchronous series capacitor(SSSC), transmitted power versus transmission angle characteristic, control range and VA rating, capability to provide real power compensation.	12
4.	**Power flow controllers:** The Unified Power Flow Controller-Basic Operating Principles, Conventional Transmission Control Capabilities, Independent Real and Reactive Power Flow Control. Control Structure, Basic Control System for P and Q Control, Dynamic Performance, The Interline Power Flow Controller (IPFC), Basic Operating Principles and Characteristics, Generalized and Multifunctional FACTS Controllers	10

4. Text Books:

T1: Understanding FACTS – Concepts and technology of Flexible AC Transmission systems, Narain G. Hingorani, Laszlo Gyugyi, IEEE Press, WILEY, 1st Edition, 2000, Reprint 2015.

T2: FACTS Controllers in Power Transmission and Distribution, Padiyar K.R., New Age International Publishers, 1st Edition, 2007

5. **References:**

R1: Flexible AC Transmission Systems: Modelling and Control, Xiao Ping Zhang, Christian Rehtanz, Bikash Pal, Springer.

6. **Course Outcomes:**

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	Understand the need for flexible AC transmission systems and identify the different types of FACTS controllers.	Analyze, Evaluating	Understand, Remember
CO2	Analyze the principles, configuration, and performance characteristics of shunt compensators like SVC and STATCOM.	Analyze, Evaluating	Understand, Apply, Evaluating
CO3	Examine static series compensation techniques and their control strategies for enhancing system stability and power transfer capability.	Application, Analysis	Understand, Apply
CO4	Apply the principles of power flow control using advanced FACTS devices such as UPFC and IPFC.	Application, Synthesis	Understand, Apply, Analyze
CO5	Evaluate the performance of FACTS controllers in improving power system stability, reliability, and efficiency.	Evaluation	Evaluate

7. **Mapping of course outcomes to module/course content:**

Module	CO1	CO2	CO3	CO4	CO5
1	3	-	2	1	-
2	1	3	-	3	-
3	-	-	-	2	3
4	-	-	1	-	3

8. **Mapping of CO to PO:**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	1	1	-	2	2	-	-	-	1
CO2	3	3	1	1	-	2	1	-	-	-	1
CO3	3	3	1	2	-	1	2	-	-	-	1
CO4	3	3	1	1	-	2	2	-	-	-	1
CO5	3	3	1	1	-	2	1	-	-	-	1

9. **Mapping to PSO:**

	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2
CO2	3	1	1	1
CO3	3	2	2	1
CO4	3	-	2	1
CO5	3	2	1	2

ADVANCED CONTROL SYSTEM

Course Code: PSM-214

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1. **Course Prerequisite:**
   1. Control system
   2. Digital signal processing
   3. Digital control

2. **Course Learning Objectives:**
   This course aims to state students with concepts of state variables; extend comprehensive knowledge of mathematical modeling of physical system; to illustrate basics of deigning a control problem; and to summarize them on theory of modern control theory.

3. **Course Name: ADVANCED CONTROL SYSTEM**
   Course Code: PSM-214
   Hours per Week: 4
   Credits: 4
   Course Content:

Module	Topics	40L
1	**Overview of Control Systems:** LTI Motion Control System; Temperature & Voltage Regulators; Modeling of Servo-motors, Hydraulic & pneumatic actuators. Computation of Relative stability using Bode plot and Nyquist method. Hierachical Control of Power System; System Control; Load scheduler and Optimiser; Real Reactive power Flow Control; AVR and Turbine Speed governor set points.	08
2	**Controller Architectures:** Design with PD Controller: Time domain interpretation of PD controller, frequency domain interpretation of PD controller, summary of the effects of PD controller. Design with PI controller: Time domain interpretation of PI controller frequency domain interpretation of PI controller, summary of the effects of PI controller, design with PID controller, Ziegler Nichols tuning & other methods. Design with lag/lead/lag-lead compensator, time domain interpretation of lag/lead/lag-lead compensator, frequency domain interpretation of lag/lead/lag-lead compensator, summary of the effects of lag/lead/lag-lead compensator.	08
3	**State space Analysis:** Introduction, concept of state, state equations for dynamic systems, state diagrams. Existence and uniqueness of solution, linear time-invariant continuous-time state equations, linear discrete-time state equations. Concept of controllability & observability, controllability and observability tests for continuous-time systems, controllability and observability of discrete-time systems, canonical forms of state models.	10
4	**Model Control:** Introduction, Effect of state feedback on controllability and observability, pole placement by state feedback; Full order observers, Reduced-order observers; deadbeat control by state feedback, deadbeat observers.	6
5	**Optimal control:** Calculus of variations and Euler–Lagrange equations, Pontryagin's Minimum Principle (PMP), Hamiltonian formulation, Linear Quadratic Regulator (LQR): Riccati equations, infinite and finite horizon, Introduction to dynamic programming and HJB equation.	8

4. **Text Books:**
   T1: Digital Control & State Variable Methods – M. Gopal, Tata Macgraw Hill.
   T2: Modern Control System Theory by M. Gopal, New Age International(P) Ltd., 2nd Edition.
   T3: Automatic Control Systems - B.C. Kuo, Prentice-Hall of India Pvt.Ltd.

5. **Reference Books:**

R1: Norman Nise, "Control System Engineering", 4th Edition. Wiley & Sons.

R2: K. Ogata, "Discrete Time Control Systems", 2nd Edition, Pearson Education.

6. **Course Outcomes:**

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	Apply the different ways of modeling of physical system and read basics of the theory of frequency domain analysis.	Identify, Apply	Understand, Apply
CO2	Describe various controller architectures and their relative performances.	Analyze	Understand, Analyze
CO3	Understand basic concepts of state-space analysis and controllability and observability.	Understand, Analyze	Understand, Apply, Analyze
CO4	Analyze the state feedback controller and observer design techniques to modern control problems and analyze the effects on transient and frequency domain response.	Understand Apply, Analyze	Understand, Analyze
CO5	Formulate and solve optimal control problems using PMP and LQR.	Understand, Analyze	Understand, Analyze

7. **Mapping of course outcomes to module / course content**

Module	CO1	CO2	CO3	CO4	CO5
1	3	-	-	2	-
2	1	3	2	-	-
3	-	-	2	2	-
4	-	-	-	3	-
5	-	1	-	2	3

8. **Mapping of the Course outcomes to Program Outcomes:**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	-	-	-	-	-	-	-	-	1
CO2	3	3	-	-	-	-	-	-	-	-	1
CO3	3	3	2	1	-	-	-	-	2	-	1
CO4	3	3	2	1	-	-	-	-	-	1	1
CO5	3	3	2	1	-	-	-	-	-	2	1

9. **Mapping to PSO:**

	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-
CO2	3	-	-	-
CO3	3	-	-	-
CO4	3	-	-	-
CO5	3	-	-	-

POWER SYSTEM MODELING AND SIMULATION

Course Code: PSM-215

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1. **Course Pre-requisites:**
   1. Power Systems Fundamentals
   2. Linear Algebra and Numerical Methods
   3. Control systems

2. **Course Learning Objectives:**

This course aims to provide students with a comprehensive understanding of the modeling and simulation techniques used in modern power systems. It introduces mathematical tools such as linear algebra, state-space methods, and transforms essential for dynamic system analysis. Students will learn to develop models of power system components and renewable energy systems, analyze system stability, and understand sensor and measurement system modeling. The course also emphasizes the practical application of simulation tools for evaluating system behavior and control strategies.

3. **Course Name: POWER SYSTEM MODELING AND SIMULATION**
   Course Code: PSM-215
   Hours per Week: 4
   Credits: 4

   Course Contents:

Module	Topics	40L
1.	**Introduction to Power System Modeling:** Overview of modern power systems, Need for modeling and simulation, Classification of models: static vs. dynamic, deterministic vs. stochastic, Modeling objectives in planning, operation, and control.	6
2.	**Mathematical Foundation for Power System Modeling:** Basics of linear algebra: state-space, eigenvalues and eigenvectors, Similarity transformation and invariants, Laplace and Z-transforms, Stability: definitions and criteria (Lyapunov, Routh-Hurwitz).	6
3.	**State Space Modelling of Power System Components:** Generator modeling (synchronous and induction machines), Excitation system and governor modeling, Transmission line and load modeling, Transformer and tap-changer models.	8
4.	**Power System Dynamics and Stability:** Small-signal stability (eigenvalue analysis), Transient stability (fault and switching analysis), Voltage stability and reactive power modeling, Frequency stability	8
5	**Renewable Energy System Modeling:** Photovoltaic (PV) system modeling and control, Wind turbine modeling (DFIG, PMSG), Inverter modeling and grid interfacing, Impact of renewables on system stability and operation, Hybrid system simulation	6
6	**Sensor and Measurement System Modeling:** Current and voltage sensor modeling (CTs, PTs), Temperature, magnetic, capacitive sensor models, Modeling with lumped and distributed parameters, Application in smart metering and monitoring	6

4. Text Books:

T1: Power System Stability and Control, Prabha Kundur, Mc Graw-Hill.

T2: Power System Dynamics: Stability and Control, J. Machowski, J. Bialek, J. Bumby, Wiley.

5. References:

R1: Power Electronics for Renewable Energy Systems, Blaabjerg, F., Teodorescu, R., Wiley.

6. Course Outcomes:

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	Understand the structure and challenges of modern power systems and the role of modeling and simulation in system planning, operation, and control	Understanding	Understand, Remember
CO2	Apply mathematical tools such as linear algebra, state-space theory, Laplace and Z-transforms to develop and analyze models of power system components and control systems.	Analyze, Evaluating	Understand, Apply, Evaluating
CO3	Model various components of power systems including generators, exciters, governors, loads, transmission lines, and transformers using state-space and dynamic models.	Application, Analysis	Understand, Apply
CO4	Analyze the dynamic behavior of power systems under small and large disturbances using stability concepts such as small-signal stability, transient stability, voltage, and frequency stability	Application, Synthesis	Understand, Apply, Analyze
CO5	Develop and simulate models of renewable energy sources (PV, wind turbines) and understand their impact on power system performance and stability.	Designing	Designing/Analyzing
CO6	Design and interpret models for sensor and measurement systems including CTs, PTs, and environmental sensors using lumped and distributed parameter techniques.	Evaluating	Designing/Evaluating

7. Mapping of course outcomes to module/course content:

Module	CO1	CO2	CO3	CO4	CO5	CO6
1	3	-	-	1	-	-
2	1	3	-	-	-	
3	-	-	3	-	1	.
4	-	-	1	3	-	-
5	-	-	-	-	3	-
6	-	-	-	1	-	3

8. Mapping of CO to PO:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	1	1	-	2	2	-	-	-	1
CO2	3	3	1	1	-	2	1	-	-	-	1
CO3	3	3	1	2	-	1	2	-	-	-	1
CO4	3	3	1	1	-	2	2	-	-	-	1
CO5	3	3	1	1	-	2	1	-	-	-	1
CO6	3	2	1	1	-	1	1	-	-	-	1

9. Mapping to PSO:

	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2
CO2	3	1	1	1
CO3	3	2	2	1
CO4	3	-	2	1
CO5	3	2	1	2
CO6	3	2	1	1

Power System Hardware Lab-II

Course Code: PSM-291

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1. Course Prerequisite:

1. Electric Power System I
2. Electric Power System II
3. Advanced Power System Analysis

2. Course Learning Objectives:

To provide students with hands-on experience in analyzing and testing complex power system components and scenarios using specialized hardware, allowing them to gain a deeper understanding of real-world power system behavior, fault conditions, protection mechanisms, and advanced control strategies.

3. **Course Name: Power System Hardware Lab-II**
Course Code: PSM 291
Hours per Week: 3
Credits: 2

Course Content:

Exp. No.	Experiments
1	Study the protection scheme of 3 phase Induction Motor against Short Circuit Fault using MICOM P220 relay
2	Study the protection scheme of 3 phase Induction Motor against Earth Fault using MICOM P220 relay
3	Study the protection scheme of 3 phase Induction Motor against Thermal Over Load using MICOM P220 relay
4	Study the protection scheme of 3 phase Induction Motor against Unbalance using MICOM P220 relay
5	Determination of Dielectric constant, tan delta and resistivity of transformer oil.
6	Determination of dielectric strength testing of insulating oil
7	Determination of A, B, C, D constants of long transmission line by π and T network method

4. Course Outcomes:

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	To familiarize with 3 phase Induction Motor against Short Circuit Fault using MICOM relay	Analyze, Identify	Understand, Analyze, Apply.
CO2	To familiarize with 3 phase Induction Motor against Earth Fault using MICOM relay	Analyze, Identify	Understand, Analyze, Apply.
CO3	To familiarize with 3 phase Induction Motor against Thermal Over Load using MICOM relay	Analyze, Identify	Understand, Analyze, Apply.

CO4	To familiarize with 3 phase Induction Motor against Unbalance using MICOM relay	Analyze, Identify	Understand, Analyze, Apply.
CO5	To measure Dielectric strength, Dielectric constant, tan delta and resistivity of transformer oil.	Analyze, Identify	Understand, Analyze, Apply.
CO6	To measure parameters of long transmission line.	Analyze, Identify	Understand, Analyze, Apply.

5. Mapping of course outcomes to module / course content:

Exp. No.	CO1	CO2	CO3	CO4	CO5	CO6
1	3	1	1	1	-	-
2	1	3	1	1	-	-
3	1	1	3	1	-	-
4	1	1	1	3	-	-
5	-	-	-	-	3	-
6	-	-	-	-	3	-
7	-	-	-	-	-	3

6. Mapping of the Course outcomes to Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	3	2	-	-	-	-	-	-	2
CO2	2	3	3	2	2	-	-	-	-	-	-	2
CO3	2	2	2	2	2	-	-	-	-	-	-	2
CO4	3	3	3	2	2	-	-	-	-	-	-	2
CO5	3	3	2	3	2	-	-	-	-	-	-	2
CO6	3	3	2	3	2	-	-	-	-	-	-	2

7. Mapping to PSO:

	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	1
CO2	3	3	2	1
CO3	3	3	2	1
CO4	2	3	2	1
CO5	3	2	2	1
CO6	3	2	2	1

Power System Software Lab-II

Course Code: PSM-292

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1. **Course Prerequisite:**
   1. Electric Power System I
   2. Electric Power System II
   3. Advanced Power System Analysis

2. **Course Learning Objectives:**
   Software Power System Lab-II course typically aims to equip students with the skills to analyze and simulate power systems using computational tools like Mi Power. Students will learn to model power system components, analyze load flow, economic load dispatch problem and simulate various power system scenarios. This includes understanding the actual behavior of transmission lines, transformers, generators, and protective devices through simulation.

3. **Course Name: Power System Software Lab II**
   Course Code: PSM 292
   Hours per Week: 3
   Credits: 2

   Course Content:

Exp. No	**Experiments**
1	Load Flow Analysis using Gauss-Seidel Method using Mi Power software
2	Load Flow Analysis using Newton -Raphson Method using Mi Power software
3	Load Flow Analysis using Fast decoupled Method using Mi Power software
4	Economic generation with B-coefficient method using Mi Power software
5	Automatic load frequency control of single area and multi-area using Matlab/Simulink software
6	Optimum power flow analysis using Matlab
7	Design of Solar photovoltaic panel using Matlab/Simulink software
8	Design of Wind turbine model using Matlab/Simulink software

4. Course outcomes:

Course Outcomes	Details/Statement	Action Verb	Knowledge Level
CO1	Ability to analyze load flow in power system network using various methods	Analyze, Identify	Understand, Remember, Apply
CO2	Ability to analyze economic generation in a power system network	Identify, Select	Understand, Apply, Analyze
CO3	Ability to control load frequency problem for isolated area and non-isolated area	Identify, analyze	Understand, Apply, Analyze
CO4	Ability to analyze the optimum power flow for a power system network	Analyze, Identify	Understand, remember, Apply, Analyze
CO5	Ability to design the module of renewable energy sources and analyze their performances.	Analyze, Identify	Analyze, Evaluate

5. Mapping of course outcomes to module / course content:

Experiments	CO1	CO2	CO3	CO4	CO5
1	3	-	-	-	-
2	3	-	-	-	-
3	3	-	-	-	-
4	2	3	-	-	-
5	-	-	3	-	-
6	2	3	1	3	-
7	-	-	-	-	3
8	-	-	-	-	3

6. Mapping of the Course outcomes to Program Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	1	1	-	-	-	-	2
CO2	3	3	3	3	3	1	1	-	-	-	-	2
CO3	3	3	3	3	3	1	1	2	-	-	1	2
CO4	3	3	3	3	3	1	2	2	-	-	2	2
CO5	3	3	3	3	3	1	3	2	-	-	3	2

7. Mapping Course outcomes to PSO:

	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	1
CO2	3	3	1	2
CO3	3	2	1	2
CO4	3	2	1	1
CO5	3	2	1	1