

Indus University
Indus Institute of Technology & Engineering
Department of Electrical Engineering

M.Tech in Electrical Engineering (Electrical Power System)

Semester I Teaching Scheme

Subject Code	Subject	Teaching Learning				Credit
		Theory Session (Hrs.)	ELC (Hrs.)	Laboratory Session (Hrs.)	Total (Hrs.)	
PS510101	Optimization Techniques	3	2		5	6
PS510102	Power System Modeling & Simulation	3		2	5	6
PS510103	Power Electronics in Power System	3			3	4
PS510104	Advanced Power System Stability	3			3	4
PS510105	Elective I	3	2		5	6
Total		15	4	2	21	26

ELC: Enhanced Learning Component

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Semester II Teaching Scheme

Subject Code	Subject	Teaching Learning				Credit
		Theory Session (Hrs.)	ELC (Hrs.)	Laboratory Session (Hrs.)	Total (Hrs.)	
PS510201	Advanced Protection & Switchgear	3		2	5	6
PS510202	Distributed Generation & Micro grid	3	2		5	6
PS510203	HVDC & FACTS devices	3			3	4
PS510204	Power System Operation & Control	3			3	4
PS510205	Elective II	3	2		5	6
Total		15	2	2	21	26

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Semester III Teaching Scheme

Subject Code	Subject	Teaching Learning				Credit
		Theory Session (Hrs.)	ELC (Hrs.)	Laboratory Session (Hrs.)	Total (Hrs.)	
PS510301	Elective III	2			2	2
PS510302	Dissertation Phase I					22
Total						24

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Semester IV Teaching Scheme

Subject Code	Subject	Teaching Learning				Credit
		Theory Session (Hrs.)	ELC (Hrs.)	Laboratory Session (Hrs.)	Total (Hrs.)	
PS510401	Dissertation Phase II					24
Total						24

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PS510101 Optimization Technique

Teaching Scheme				Examination Scheme			
Theory Hrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	30	00	4	60	25	15	100

Course Purpose

To learn the concepts and techniques of evolutionary and optimization techniques in power system applications.

Course Objectives

- To have knowledge on optimization techniques applied to power systems.
- To understand the different evolutionary computation techniques and multi objective optimization and their applications in power systems.

Course Contents

[Unit 1]

[09]

Linear programming, formulation-Graphical and simplex methods-Big-M method-Two phase method-Dual simplex method-Primal Dual problems.

[Unit 2]

[09]

Unconstrained one dimensional optimization techniques -Necessary and sufficient conditions – Unrestricted search methods-Fibonacci and golden section method-Quadratic Interpolation methods, cubic interpolation and direct root methods.

[Unit 3]

[09]

Unconstrained n dimensional optimization techniques – direct search methods –Random search –pattern search and Rosen brooch’s hill claiming method- Descent methods-Steepest descent, conjugate gradient, quasi -Newton method.

[Unit 4]**[09]**

Constrained optimization Techniques- Necessary and sufficient conditions –Equality and inequality constraints-Kuhn-Tucker conditions-Gradient projection method-cutting plane method- penalty function method .

[Unit 5]**[09]**

Dynamic programming- principle of optimality- recursive equation approach-application to shortest route, cargo-loading, allocation and production schedule problems.

Reference books:

1. Rao,S.S.,“ Optimization :Theory and Application” Wiley Eastern Press, 2nd edition 1984.
2. Taha,H.A., Operations Research –An Introduction,Prentice Hall of India,2003.
3. Fox, R.L., „Optimization methods for Engineering Design” , Addition Welsey, 1971.

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PS510102 Power System Modeling & Simulation

Teaching Scheme				Examination Scheme			
Theory Hrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	00	30	6	60	25	15	100

Course Purpose

To enable the students to develop the understanding of the steady state analysis of power system.

Course Objectives

- To impart knowledge on dynamic modelling of a synchronous machine in detail.
- To describe the modelling of excitation and speed governing in detail.
- To gain knowledge on static & Dynamic Load and transmission line Modeling.
- To understand the concept of Faults and short-circuit studies.

Course Contents

[Unit 1] Synchronous Machine Concept & Modeling [15]

Physical Description, Armature & Field Structure, MMF waveforms, direct & quadrature axis, Mathematical Description of synchronous machine, review of magnetic circuit, Basic equation of synchronous machine, Parks transformation, Classification of synchronous machine modelling as per IEEE, Electrical Transient performance characteristics for Synchronous machine, 3 phase short circuit at terminal of Synchronous machine, Magnetic saturation, Improve of modelling of saturation, Equation of Motion.

[Unit 2] Modeling of Speed Governing & Excitation System [12]

Introduction, Modeling of Speed governing System, Mechanical and Electro hydraulic controlled speed governing system, General Model for speed governing system, Introduction to excitation system, Excitation System Schematic diagram with elements of excitation system, D.C. excitation systems, A.C. excitation systems, over excitation and under excitation limiters.

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PS510103 Power Electronics in Power System

Teaching Scheme				Examination Scheme			
Theory Hrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	00	00	4	60	25	15	100

Course Purpose

To enable the students gain a fair knowledge on the concepts of advanced power electronics devices and its application in power system.

Course Objectives

- To emphasise the need of Power Electronics Devices
- To learn the characteristics, applications and modelling of SCR converters.
- To analyse the interaction of different compensators and phase regulators.

[Unit 1]

Advanced Power Semiconductor devices

[09]

Diode Rectifiers: Single phase and three phase rectifiers with R, R-L and RC load
Advanced Power Semiconductor devices: voltage current characteristics and switching characteristics of SCR BJT, MOSFET, IGBT, MCT and GTO. Application of devices.

[Unit 2]

Thyristor Converters

[09]

Thyristor Converters: Single phase and Three phase half wave and full wave rectifier converters with R and RL load. Continuous Conduction and Discontinuous conduction Mode.
Thyristor Inverters: Single phase inverters. Three phase bridge inverters. Single Phase Input Line Current Harmonics and Power Factor- Inverter Mode of Operation - Dual Converters Switch-Mode dc-ac Inverters. Basic Concepts.

[Unit 3]**Static Series Compensators****[09]**

Objective of series compensation, Variable impedance type series compensators, Concept of series compensators, Thyristor switched series capacitor (TSSC), Thyristor controlled series capacitor (TCSC), Basic Operating Control Schemes for TSSC, Basic Operating Control Schemes for TCSC, Switching converter type series compensations: Static synchronous series compensator (SSSC)

[Unit 4]**Voltage and Phase Regulators****[09]**

TCVR and TCPAR, Objective of voltage and phase angle regulators, Power flow control by phase angle control, Thyristor controlled voltage regulator (TCVR), Thyristor controlled phase angle regulators (TCPAR) Switching converter based voltage and phase angle regulators, Hybrid phase angle regulators, Static Phase Shifters

[Unit 5]**Power Quality Problems in Distribution Systems****[09]**

Power quality, Power quality evaluation procedure, General classes of power quality problems Transients, voltage variations: long-duration and short duration, voltage imbalance, voltage sags Transients, voltage variations: voltage flicker, waveform distortions, power frequency variations

Text Book:

1. M.H. Rashid, Power Electronics, Circuits, Devices, and Applications, Pearson, IIIrd Edition 2003.
2. T.J.E. Miller, Static Reactive Power Compensation, John Wiley & Sons, New York.
3. Ned Mohan, Tore M. Undeland, and William P. Robbins, "Power Electronics: Converters, Applications and Design", 3rd edition, John Wiley & Sons, 2003.

Reference Book:

1. D. M. Tagare, "Reactive Power Management", Tata McGraw-Hill, 2004
2. Math H. J. Bollen, "Understanding Power Quality Problems: Voltage Sags and Interruptions", Standard Publishers Distributors, 2000.
3. E. Acha, V. G. Agelidis, O. Anaya Lara, and T. J. E. Miller, "Power Electronic Control in Electrical Systems", Elsevier Science, 2005.
4. Theodore Wildi, "Electrical Machines Drives and Power Systems", 5th edition, Pearson Education Asia Pvt. Ltd., 2002.
5. P. S. R. Murty, "Operation and Control in Power Systems", B S Publication, 2005.
6. G.T. Heydt, Power Quality, Stars in a Circle Publication, Indiana.

7. Kalyan K. Sen, Mey Ling Sen : Introduction to FACTS Controllers, Theory, Modeling and Applications, 1st edition, IEEE Press, John Wiley & Sons, New Jersey.
8. Recent papers of IEEE Trans. on Power Electronics, IEEE Trans. on Industrial Electronics, IEEE Trans. on Industry Applications, IEEE Trans. on Power Systems, IEEE Trans. on Power Delivery etc

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PS510104 Power System Dynamics & Stability

Teaching Scheme				Examination Scheme			
TheoryHrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	00	00	4	60	25	15	100

Course Purpose

To enable the students to develop understanding of power system components modelling and Small-Signal stability analysis in power system.

Course Objectives

- To understand and enhance small signal stability and Multi machine problem of power systems.
- To understand the fundamental concepts of Voltage & Transient Stability.
- Concept of Torsional effect and its characteristics

Course Contents

[Unit 1] Introduction to Power System Stability Problem [06]

Introduction, Basic Concept of Power system stability problem, Rotor angle stability, Concept of Voltage collapse, mid-term and long term stability, classification of stability, Review of Stability Problem

[Unit 2] Small Signal Stability for Single Machine & Multi Machine System [12]

Small signal stability of single machine infinite bus system by means of Classical model, block diagram representation, effect of excitation system, effect of AVR and Damping torque component, Power System stabilizer, Small signal stability for multi machine system, Formulation of state Equation, representation of static load, Analysis of large system and AESOPS algorithms

[Unit 3] Torsional Characteristics & Sub Synchronous Oscillation [09]

Introduction, Turbine-generator torsional Characteristics, Shaft system Model Torsional interaction with Power System Control, Subsynchronous resonance, Characteristics of series capacitor, Self excitation due to induction generator effect, analytical method and torsional interaction resulting SSR, Countermeasures to SSR Problems

[Unit4] Voltage Collapse & Stability [09]

Basic concept of Voltage stability, Comparison of Angle and Voltage stability, Typical scenario of voltage collapse, Classification of voltage stability, Voltage stability analysis, Modeling requirements, Dynamic Analysis

[Unit 5] Transient Stability [09]

Basic concept of transient stability, Simulation of dynamic system, structure of power system, excitation system representation, Analysis of unbalanced faults, Symmetrical components, sequence impedances, Simulation of different types of faults, Case study of transient stability of large machine system

Text\ Reference Books:

1. P. S. Kundur Power System Stability and Control, McGraw Hill Inc, New York.
2. K.R.Padiyar - Power System Dynamics - Stability and Control, BS Publishers, Hyderabad
- 3.. J. Machowski, J.W. Bialek, J.R. Bumby - Power System Dynamics, Stability and Control, Wiley publishers
- 4.. P.Sauer and M.A.Pai - Power System Dynamics and Stability, Prentice Hall.
5. Ajarappa - The Techniques for Computation of Voltage Stability Assessment, Wiley IEEE Press
6. I. J. Nagrath and D. P. Kothari - Modern Power Systems Analysis, Tata McGraw Hill.

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PS510105 Alternate Energy Sources

[Unit 1]

Introduction

[09]

Recent trends in energy consumption - World energy scenario - Energy sources and their availability - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems - need to develop new energy technologies.

[Unit 2]

Wind Energy Conversion System

[09]

Basic principle of wind energy conversion - nature of wind - Wind survey in India - Power in the wind - components of a wind energy - conversion system - Performance of induction generators for WECS - classification of WECS - Analysis of different wind power generators - IG - PMSG - DFIG – SEIG.

[Unit 3]

Grid Connected Wind Energy System

[09]

Grid Connected WECS: Grid connectors concepts - wind farm and its accessories - Systems for Feeding into the Grid - Induction Generators for Direct Grid Coupling - Asynchronous Generators in Static Cascades - Synchronous Generators Grid related problems - Generator control - Performance improvements - Different schemes - AC voltage controllers - Harmonics and PF improvement.

[Unit 4]

Solar Energy Conversion System

[09]

Photovoltaic Energy Conversion: Solar radiation and measurement - solar cells and their characteristics -PV arrays - Electrical storage with batteries - Switching devices for solar energy conversion Grid connection Issues - Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection of inverter, battery sizing, array sizing.

PV Applications: Stand alone inverters - Charge controllers - Water pumping, audio visual equipments, street lighting - analysis of PV systems.

[Unit 5]

Operation of Power System with Wind and Solar energy Systems

[09]

Interface requirement – synchronizing with grid – operating limit – energy storage and load scheduling – utility resource planning – electrical performance – voltage, current and power efficiency – component design for maximum efficiency – static bus impedance and voltage regulation – quality of power – renewable capacity limit – Plant economy.

References:

1. Thomas Ackermann, “*Wind Power in Power Systems*”, John Wiley & Sons, Ltd, 2005.
2. Mukund R. Patel, “*Wind and Solar Power Systems*”, CRC Press, 1999.
3. Muhammed H. Rashid, “*Power Electronics Handbook*”, Academic Press, Second edition, 2006.
4. Rao. S. & Parulekar, “*Energy Technology*”, Khanna publishers, Fourth edition, 2005.
5. Rai ,G.D., “*Non- conventional resources of energy*”, Khanna publishers ,Fourth edition , 2010.
6. Bansal N K, Kleeman and Meliss, “*Renewable energy sources and conversion Techniques*”, Tata McGraw hill, 1990.

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PS510201 Advanced Protection & Switchgear

Teaching Scheme				Examination Scheme			
Theory Hrs.	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	00	02	6	60	25	15	100

Course Purpose

To impart knowledge on various aspects of protective relaying for power system components

Course Objective

- To Review of Power System Protection
- The concept of Digital Protection
- To analyse Numerical Protection algorithm and Filtering system
- To analyse distance and carrier protection
- To familiarize the concepts of Busbar protection and Power apparatus Protection

Course Contents

[Unit 1] Principle of Power System Protection [09]

Review of principles of power system protection, Classification of relay and control system, over current protection, Distance protection, Directional protection, Differential protection, System protection, Desirable Attributes of Protection.

[Unit 2] Numerical (digital) Protection [10]

Introduction, advantages of Numerical relays, Comparison of electromagnetic, static and digital relay, Block diagram and components of digital relay, Numerical over current protection, Numerical distance protection, Numerical impedance relay, Numerical reactance relay, Numerical mho relay, Block diagram and interface for directional relay.

[Unit 3] Numerical Relaying Algorithm & Filtering [10]

Architecture of Digital relays, Sampling theorem, Least Square Method for Estimation of Phasors, Co-Relation with reference wave, Fourier analysis of analogous Signals, Discrete

fourier transform, Walsh–Hadamard analysis, Digital Filtering, Simple low-pass filter, Simple high-pass filter, FIR filter, IIR filters, Comparison between FIR & IIR filters.

[Unit 4] Carrier Aided protection for Transmission Line

[06]

Requirement for carrier-aided protection, Coupling and trapping the carrier signals into the desired line section, Unit type carrier-aided directional comparison relaying, Carrier-aided distance schemes acceleration Zone II, Phase comparison relaying carrier protection.

[Unit 5] Power apparatus Protection

[10]

Generator Protection-Stator-Rotor Earth Fault Protection, Protection against unbalanced loading and loss of Excitation, under frequency and over voltage protection Numerical approach for generator protection.

Transformer Protection-Concept of Gas operated relay, Restricted earth fault protection, Protection against over fluxing, Numerical Approach for Transformer protection, **Buszone Protection**- Requirements, Unit and non-Unit protection, Breaker Back up protection.

References:

Here is a short list of reference books which may be useful for further reading in Protection & Switchgear relevant to the experiments.

1. Oza, Bhuvanesh, Nair, N.C., Mehta, R.P., Makwana V.H., “Power System Protection and Switchgear,” Tata McGraw-Hill, New Delhi, 2010.
2. Rao, S.S., “Switchgear and Protection: theory, practice and solved problems,” Khanna Publisher, New Delhi.
3. Paithankar, Y.G., Bhide, S.R., “Fundamentals of Power System Protection,” PHI Learning Pvt. Ltd., New Delhi.
4. Mason C.R., “The Art & Science of Protective Relaying,” Wiley Eastern Ltd.
5. Ravindranath, B., Chander, M., Power System Protection and Switchgear,” New Age international (P) Ltd, New Delhi.
6. Badri Ram, Vishwakarma, D.N., “Power System Protection and Switchgear,” Tata McGraw-Hill, New Delhi.
7. Singh Ravindra P. “Switchgear and Power System Protection” PHI Learning Pvt.Ltd., New Delhi.
8. Bhavesh Bhalja, Maheshwari, Nilesh Chothani “Protection & Switchgear” OUP India.
9. J.B.Gupta “Switchgear and Protection” S. K. Kataria & Sons, India-2009.
10. Anderson, P.M., “Power System Protection,” Wiley-IEEE Press, 1998.

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PS510202 Distributed Generation & Micro grid

Teaching Scheme				Examination Scheme			
Theory Hrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	30	00	6	60	25	15	100

Course Purpose

To provide knowledge on the various aspects of distributed generations and micro grids.

Course Objectives

- To illustrate the concept of distributed generation.
- To analyze the impact of grid integration.
- To study concept of Microgrid and its configuration.

Course Contents

[Unit 1] Introduction [09]

Conventional power generation: advantages and disadvantages, Energy crises, Non-conventional energy (NCE) resources: review of Solar PV, Wind Energy systems, Fuel Cells, micro-turbines, biomass, and tidal sources.

[Unit 2] Distributed Generation (DG) [09]

Concept of distributed generations, topologies, selection of sources, regulatory standards/framework, Standards for interconnecting Distributed resources to electric power systems: IEEE 1547. DG installation classes, security issues in DG implementations. Energy storage elements: Batteries, ultra-capacitors, flywheels. Captive power plants

[Unit 3] Impact of grid Integration [09]

Requirements for grid interconnection, limits on operational parameters,: voltage, frequency, THD, response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability, stability and power quality issues.

[Unit 4] Basics of Microgrid

[09]

Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids,

[Unit 5] Control & Operation of Microgrid

[09]

Modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques, microgrid communication infrastructure, Power quality issues in microgrids, regulatory standards, Microgrid economics, Introduction to smart microgrids.

REFERENCES

1. "Voltage Source Converters in Power Systems: Modeling, Control and Applications", Amirnaser Yezdani, and Reza Iravani, IEEE John Wiley Publications.
2. "Power Switching Converters: Medium and High Power", Dorin Neacsu, CRC Press, Taylor & Francis, 2006.
3. "Solar Photo Voltaics", Chetan Singh Solanki, PHI learning Pvt. Ltd., New Delhi, 2009
4. "Wind Energy Explained, theory design and applications," J.F. Manwell, J.G. McGowan Wiley publication
5. "Biomass Regenerable Energy", D. D. Hall and R. P. Grover, John Wiley, New York, 1987.

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PS510203 HVDC & FACTS Devices

Teaching Scheme				Examination Scheme			
Theory Hrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	00	00	4	60	25	15	100

Course Purpose

To mould the students to acquire knowledge about HVDC Transmission systems.
To enable the students gain a fair knowledge on the concepts and technology of flexible AC transmission systems.

Course Objectives

- This course gives idea about modern trends in HVDC Transmission and its application.
- Complete analysis of harmonics and basis of protection for HVDC Systems.
- To emphasis the need for FACTS controllers.
- To learn the characteristics, applications and modelling of series and shunt FACTS controllers.

Course Contents

[Unit 1] DC Power Transmission Technology [06]

Introduction - Comparison of AC and DC transmission – Application of DC transmission – Classifications of DC transmission system - Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables, VSC based HVDC. Comparison of Line Commutated Converter (LCC) link and Voltage Source Converter (VSC) link.

[Unit 2] Analysis of HVDC Converters [06]

Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters

[Unit 3] Multi terminal HVDC & Harmonics [06]

Introduction – Potential applications of MTDC systems - Types of MTDC systems - Control and protection of MTDC systems - Study of MTDC systems- parallel operation of AC and DC transmission.

[Unit 4] Introduction to FACTS Controller [09]

Control of power flow in AC transmission line- Analysis of uncompensated AC Transmission line- Passive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer- Need for FACTS controllers- types of FACTS controllers.

[Unit 5] Static VAR Compensators [09]

Configuration of SVC- voltage regulation by SVC- Modelling of SVC for load flow analysis- Modelling of SVC for stability studies-Design of SVC to regulate the mid-point voltage of a SMIB system- Applications: transient stability enhancement and power oscillation damping of SMIB system with SVC connected at the mid-point of the line.

[Unit 6] Voltage Source Converters based FACTS Devices [09]

Static synchronous compensator(STATCOM)- Static synchronous series compensator(SSSC)- Operation of STATCOM and SSSC-Power flow control with STATCOM and SSSC- Modelling of STATCOM and SSSC for power flow and transient stability studies –operation of Unified and Interline power flow controllers(UPFC and IPFC)- Modelling of UPFC and IPFC for load flow and transient stability studies- Applications.

Text Book:

1. Narain G. Hingorani, Laszlo Gyugyi, “Understanding FACTS Concepts and Technology of Flexible AC Transmission System”, Standard Publishers, Delhi, 2001.
2. Mohan Mathur, R., Rajiv. K. Varma, “Thyristor – Based FACTS Controllers for Electrical Transmission Systems”, IEEE press and John Wiley & Sons, Inc, 2002.

Reference Book:

1. K.R.Padiyar, “FACTS Controllers in Power Transmission and Distribution”, New Age International (P) Ltd., Publishers, New Delhi, Reprint, 2008.
2. A.T. John, “Flexible AC Transmission System”, Institution of Electrical and Electronic Engineers (IEEE), 1999.
3. K.Sood, “HVDC and FACTS controllers- Applications of Static Converters in Power System”, Kluwer Academic Publishers, 2004.

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PS510204 Advanced Power System Operation & Control

Teaching Scheme				Examination Scheme			
Theory Hrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	00	00	4	60	25	15	100

Course Purpose

To enable the students acquire a comprehensive idea on various aspects of power system operation and control.

Course Objective

- To gain knowledge on economic operation of power system and its solution techniques.
- To understand Optimal Power flow & Unit Commitment.
- To get the insight of load frequency control and its modeling
- To get insight of contingency analysis problem and the solution methods.

Course Contents

[Unit 1] Power Flow Study & Modeling [09]

Satic Load flow Equation formation, Disturbance variables, control variables & state variables, practical constraints, types of buses, Gauss iterative method, algorithm, flow chart and programming, Gauss-Seidal without PV buses, algorithm, flowchart and programming, Gauss-Seidal with PV buses, algorithm, flowchart and programming, Newton-Raphson method without PV buses, algorithm, flowchart and programming, Newton-Raphson method with PV buses, algorithm, flowchart and programming, Fast Decoupled Load Flow method (FDLF), algorithm, flowchart and programming

[Unit 2] Economic Load Dispatch & Hydrothermal Scheduling [09]

Introduction – input-output characteristics, cost curves, heat rate curve, incremental fuel rate curve, different constraints, Economic allocation of generation without transmission losses, algorithm and flowchart, programming, Transmission loss formula in terms of loss coefficients
Economic allocation of generation with transmission losses, algorithm and flowchart, programming,

[Unit 3] Optimal Power Flow and Unit Commitment**[09]**

Optimal real and reactive power dispatch without inequality constraints, Optimal real and reactive power dispatch with inequality constraints, Introduction to UC, Comparison with Economic Load dispatch, Constraint in UC, Cost function formulation, Unit commitment solution by enumeration scheme, priority list method and Dynamic programming, Optimal Unit commitment with security Constraint

[Unit 4] Optimal Frequency Control**[09]**

P-f and Q-V control loops, Mechanism of real and reactive power control regulators, Steady state frequency error, dynamic frequency error, droop characteristics, P-f controller strategy for isolated area, steady state and dynamic frequency response, Two area tie-line bias control strategy, Flat frequency control, selective frequency control, tie line frequency control, Design of optimal state controller using Kalman method, State space representation of two area control, Sub-optimal and decentralized controllers, Discrete-mode AGC, Time-error and inadvertent interchange correction techniques

[Unit 5] Load Forecasting Technique**[09]**

Introduction, Forecasting Methodology, Estimation of average and Trend Terms, Estimation of Periodic Components, Time Series Approach, Estimation of Stochastic Components, Long Term prediction using Economic Models, Reactive Load forecast

Reference books:

1. W. D. Stevenson - Elements of Power System Analysis, McGraw Hill Book Company, New York
2. S. S. Vadhwa - Power System Analysis and Stability, Khanna Publishers, New Delhi.
3. O. I. Elgerd - Electric Energy System Theory: An Introduction, TMH Ltd., New Delhi.
4. L. K. Kirchner - Economic Operation of Power System, John Wiley and Sons, Inc., New York.
5. P. S. R. Murty - Power System Operation and Control, TMH Publications, New Delhi.

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PS510205 Power System Transients

Teaching Scheme				Examination Scheme			
Theory Hrs	ELC	LAB	Credits	University Examination	Mid Sem Examination	Continuous Evaluation	Total Marks
45	00	30	6	60	25	15	100

[Unit 1] Fundamental concepts of Switching transients in power system [09]

Introduction, sources of electrical transients, Transient analysis of three phase power systems, Switching transients : The short line fault, Circuit breakers, Circuit breaker recovery voltage, Modelling of the switching arc of Circuit breakers

[Unit 2] Wave Propagation on single and multiconductor system [09]

Introduction, velocity of travelling waves and characteristics impedance, wave equation, Wave propagation on multiconductor system, wave equation, Transition points in multiconductor system, Reflection and refraction of travelling waves, lattice diagram, Effect of dissipation on wave propagation, Effect of finite soil conductivity, Modal analysis, Ground impedance

[Unit 3] Lightning phenomena and Switching surge phenomena [09]

Mechanism of the lightning flash, Wave shapes of the lightning currents, Direct lightning stroke to transmission line tower and, Direct lightning stroke to a line, Grounding for protection against lightning, Steady state Tower-Footing resistance, Dynamic tower footing resistance, concentrated and extended grounding system,

Introduction, Current suppression or chopping, Switching surges in capacitive circuits, System performance under switching surges, mechanism of air breakdown, Critical flashover voltage of insulation under switching surges, Phase to phase switching surges

[Unit 4] Response of overhead lines to lightning strokes [09]

Direct lightning stroke to overhead lines without shielding wires, introduction, stroke to tower, Direct lightning stroke to overhead lines with shielding wires, introduction, stroke to tower, stroke to shield wire, Lightning induced voltages on overhead lines of finite length, Surge arrestors, introduction, and type.

The electromagnetic transient program, The MNA program, The Xtrans program, Insulation co-ordination, Introduction ,terminology , basic requirement, Classification of insulation for insulation coordination, Application of insulation coordination, Insulation coordination in high voltage dc system

Reference Books:

1. C.S.Indulkar&D.P.K othari - Power System Transients: A statistical approach -Prentice Hall.
2. V. Venicov - Transient Processes in electrical power systems-Mir publishers
3. Lou Van Der Sluis - Transients in electrical power systems, John Wiley& Sons publishers

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List of Electives

- Advanced Digital Signal Processing
- Power quality
- Smart Grid
- Industrial Power system Design
- Application of A.I. Power System
- Power System Security
- Advanced Software Techniques for Power System Analysis
- Alternate Energy Sources

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Energy Management & Audit

[Unit 1] Introduction [09]

Need for energy management – energy basics – designing and starting an energy management program – energy accounting – energy monitoring, targeting and reporting- energy audit process.

[Unit 2] Energy Cost and Management [09]

Important concepts in an economic analysis – economic models – time value of money –utility rate structures – cost of electricity – loss evaluation.

Load management: demand control techniques – utility monitoring and control system-HVAC and energy management – economic justification.

[Unit 3] Energy management for Motors, Systems and Electrical Equipment [09]

Systems and equipment – electric motors – transformers and reactors – capacitors and synchronous machines.

[Unit 4] Metering for Energy Management [09]

Relationships between parameters – Units of measure – typical cost factors – utility meters – timing of meter disc for kilowatt measurement – demand meters – paralleling of current transformers – instrument transformer burdens – multitasking solid-state meters – metering location vs. requirements – metering techniques and practical examples.

[Unit 5] Lighting System & Co-Generation [09]

Concept of lighting systems – the task and the working space – light sources – ballasts – luminaries – lighting controls – optimizing lighting energy – power factor and effect of harmonics on power quality – cost analysis techniques – lighting and energy standards.

Cogeneration: forms of cogeneration – feasibility of cogeneration – electrical interconnection.

References:

1. Eastop T.D and Croft D.R, “Energy Efficiency for Engineers and Technologists”, Logman Scientific & Technical, 1990.
2. Reay D.A., “Industrial Energy Conservation”, first edition, Pergamon Press, 1977.

3. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.
4. Amit K. Tyagi, "Handbook on Energy Audits and Management", TERI, 2003.
5. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, "Guide to Energy Management", Fifth Edition, The Fairmont Press, Inc., 2006.

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Smart Grid

[Unit 1] Smart Grid Architectural Design [09]

Introduction – Comparison of Power grid with Smart grid – power system enhancement – communication and standards - General View of the Smart Grid Market Drivers - Stakeholder Roles and Function - Measures - Representative Architecture - Functions of Smart Grid Components-Wholesale energy market in smart grid-smart vehicles in smart grid.

[Unit 2] Smart Grid Communication and Measurement Technology [09]

Communication and Measurement - Monitoring, Phasor Measurement Unit (PMU), Smart Meters, Wide area monitoring systems (WAMS)- Advanced metering infrastructure- GIS and Google Mapping Tools.

[Unit 3] Performance analysis Tool for Smart Grid Design [09]

Introduction to Load Flow Studies - Challenges to Load Flow in Smart Grid and Weaknesses of the Present Load Flow Methods - Load Flow State of the Art: Classical, Extended Formulations, and Algorithms –Load flow for smart grid design-Contingencies studies for smart grid.

[Unit 4] Stability Analysis Tool for Smart Grid [09]

Voltage Stability Analysis Tools-Voltage Stability Assessment Techniques-Voltage Stability Indexing-Application and Implementation Plan of Voltage Stability in smart grid-Angle stability assessment in smart grid-Approach of smart grid to State Estimation-Energy management in smart grid.

[Unit 5] Renewable Energy and Storage [09]

Renewable Energy Resources-Sustainable Energy Options for the Smart Grid-Penetration and Variability Issues Associated with Sustainable Energy Technology-Demand Response Issues-Electric Vehicles and Plug-in Hybrids-PHEV Technology-Environmental Implications-Storage Technologies-Grid integration issues of renewable energy sources.

References:

1. James Momoh, "Smart Grid: Fundamentals of design and analysis", John Wiley & sons Inc, IEEE press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", John Wiley & sons inc, 2012.
3. Fereidoon P. Sioshansi, "Smart Grid: Integrating Renewable, Distributed & Efficient Energy", Academic Press, 2012.
4. Clark W.Gellings, "The smart grid: Enabling energy efficiency and demand response", Fairmont Press Inc, 2009.

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Power Quality

[Unit 1] Power Quality & Overview [09]

Power Quality definition, PQ characterization: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation–Power acceptability curves: CBEMA, ITIC – Sources for Electric Power Quality problem in power system: poor load power factor, Non linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage – Power quality standards and Guidelines.

[Unit 2] Voltage Variation [09]

Voltage Sags - Magnitude & duration-Types- Sources of sags - Estimation of Voltage sag performance: Transmission system and Utility distribution system, Effect of sag on AC Motor Drives, Single-Phase Domestic and Office Loads, Monitoring and mitigation of voltage sag. Origin of Long & Short interruption -influence on various equipments-Basic reliability indices related interruption-monitoring and mitigation of interruption.

[Unit 3] Power Quality Analysis [09]

Measurements of Voltage, Current, Power, Energy, power factor- Time domain methods and Frequency domain methods: Laplace's, Fourier and Hartley transform – The Walsh Transform – Wavelet Transform. Harmonic Distortion, Voltage versus Current Distortion, Harmonics versus Transients, Harmonic Indexes, Harmonic Sources from Commercial Loads, Harmonic Sources from Industrial Loads.

[Unit 4] Power Quality Monitoring [09]

Monitoring considerations: Power line disturbance analyser, power quality measurement equipment, harmonic / spectrum analyser, flicker meters, disturbance analyser. Analysis of power outages, Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers, Analysis of distortion: On-line extraction of fundamental sequence components from measured samples

[Unit 5] Power Quality Enhancement [09]

Utility-Customer interface –Harmonic filters: passive, Active and hybrid filters –Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM, Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC –control strategies:

P-Q theory, Synchronous detection method – Custom power park –Status of application of custom power devices.

References:

1. Math H.J.Bollen, “Understanding Power Quality Problems-Voltage sag & Interruptions”, IEEE Press, 2000.
2. Arindam Ghosh “Power Quality Enhancement Using Custom Power Devices”, Kluwer Academic Publishers, 2002.
3. Roger.C.Dugan, Mark.F.McGranaghan, Surya Santoso, H.Wayne Beaty, “Electrical Power Systems Quality”, McGraw Hill, 2003.
4. G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition).
5. Jos Arrillaga, Neville R. Watson, “ Power System Harmonics”- John Wiley & Sons, 2003.

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Energy Management & Audit

[Unit 1] Introduction [09]

Need for energy management – energy basics – designing and starting an energy management program – energy accounting – energy monitoring, targeting and reporting- energy audit process.

[Unit 2] Energy Cost and Management [09]

Important concepts in an economic analysis – economic models – time value of money –utility rate structures – cost of electricity – loss evaluation.

Load management: demand control techniques – utility monitoring and control system-HVAC and energy management – economic justification.

[Unit 3] Energy management for Motors, Systems and Electrical Equipment [09]

Systems and equipment – electric motors – transformers and reactors – capacitors and synchronous machines.

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10. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, “Guide to Energy Management”, Fifth Edition, The Fairmont Press, Inc., 2006.

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Digital Signal Processing

[Unit 1] Discrete Time System [09]

Characteristics and classification of signals – Representation and classification of Discrete time systems – Advantages of Digital Signal processing – transfer functions – Z-transform, inverse Z-transform and its applications – convolution.

[Unit 2] Fourier Transforms [09]

Introduction to analysis of analog and discrete signals – Fourier series, Fourier transform – Discrete Fourier Transform (DFT) properties of DFT – Computation of discrete Fourier transforms – Radix – 2 FFT algorithms.

[Unit 3] Sampling [09]

Sampling of continuous signals – analog filter design – anti aliasing filters – Sample and hold circuits – Reconstructing fillers – Digital to analog and analog to digital converters.

[Unit 4] FIR & IIR Filter Design [09]

Realization of FIR and IIR Filters – Impulse invariance and Bilinear transform methods of IIR filter design – Design of FIR filter using windows – Comparison of IIR and FIR Digital filters.

[Unit 5] Finite Length Word Effect and Quantisation [09]

Introduction – Effects of coefficient on Quantization – Finite register length effects in realizations of Digital filters and discrete Fourier transform computation.

Architecture and features of Texas and Analog Devices DSP processors – Advantages.

References:

1. Alan V. Oppenheim, Ronald W. Schaffer “*Digital Signal Processing*”, Prentice Hall of India pvt. Ltd., 2002.
2. John G. Proakis, Dimitris G. Manoiaias, “*Digital Signal Processing*”, Prentice Hall of India pvt. Ltd., third edition 2000.
3. Sanjit K. Mitra “*Digital Signal Processing*”, Tata McGraw Hill, second edition, 2001.
4. Alan V. Oppenheim, Ronald W. Schaffer, “*Discrete time Signal processing*”, Prentice Hall of India pvt. Ltd., 1998.

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Advanced Software Techniques for Power System Analysis

[Unit 1] Introduction [09]

Introduction of soft computing - soft computing vs. hard computing- various types of soft computing techniques- applications of soft computing-Neuron- Nerve structure and synapse- Artificial Neuron and its model- activation functions- Neural network architecture- single layer and multilayer feed forward networks- McCullochPitts neuron model- perceptron model- Adaline and Madaline- multilayer perception model- backpropagation learning methods- effect of learning rule coefficient -back propagation algorithm- factors affecting back propagation training- applications.

[Unit 2] Artificial Neural Network [09]

Counter propagation network- architecture- functioning & characteristics of counter-Propagation network-Hopfield/ Recurrent network- configuration- stability constraints- associative memory- and characteristics- limitations and applications- Hopfield v/s Boltzman machine- Adaptive Resonance Theory- Architecture- classifications-Implementation and training-Associative Memory.

[Unit 3] Fuzzy Logic System [09]

Introduction to crisp sets and fuzzy sets- basic fuzzy set operation and approximate reasoning.Introduction to fuzzy logic modeling and control- Fuzzification-inferencinganddefuzzification-Fuzzy knowledge and rule bases-Fuzzy modeling and control schemes for nonlinear systems.Self organizing fuzzy logic control- Fuzzy logic control for nonlinear time delay system.

[Unit 4] Genetic Algorithm [09]

Basic concept of Genetic algorithm and detail algorithmic steps-adjustment of free Parameters- Solution of typical control problems using genetic algorithm- Concept on some other search techniques like tabu search and ant colony search techniques for solving optimization problems.

[Unit5] Applications [09]

GA application to power system optimization problem- Case studies: Identification and

control of linear and nonlinear dynamic systems. using software-Neural Network toolbox.
Stability analysis of Neural Network interconnection systems- Implementation of fuzzy
logic controller using Matlab fuzzy logic toolbox-Stability analysis of fuzzy control
systems.

References

1. Laurene V. Fausett, Fundamentals of Neural Networks: Architectures, Algorithms And Applications, Pearson Education,
2. Timothy J. Ross, "Fuzzy Logic with Engineering Applications" Wiley India.
3. Zimmermann H.J. "Fuzzy set theory and its Applications" Springer international edition, 2011.
4. David E. Goldberg, "Genetic Algorithms in Search, Optimization, and Machine Learning", Pearson Education, 2009.
5. W.T. Miller, R.S. Sutton and P.J. Werbos, "Neural Networks for Control", MIT Press, 1996.

5. Generation of Electrical Energy – B.R. Gupta, S. Chand Publications

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Applications of Artificial Intelligence in Power System

[Unit 1] Introduction to Artificial Intelligence [09]

Introduction, Fuzzy systems, Artificial Neural Network (ANN), Expert Systems, Genetic Algorithm, Evolutionary Programming. Biological neurons: Function of single biological neuron, function of artificial neuron, Basic terminology related to artificial neuron. Characteristics of ANN, Typical applications of ANN such as classification, pattern recognition, forecasting Properties, strength of NN,

[Unit 2] Different Architectures of ANN and Learning Processes: [06]

Different architectures of Neural Network, types of activation function, concept of Learning with a Teacher, Learning without a Teacher, Learning Tasks.

[Unit 3] Single Layer Network and Multi-layer Network [09]

Single Layer Perceptron: architecture – training algorithm, Least– Mean square algorithm, learning curves, Learning Rate, Annealing techniques. Feed forward Neural Network (MLP), Back propagation algorithm. Limitation of Back-propagation algorithm. Concept of learning rate, momentum coefficient, Generalization capacity

[Unit 4] Fuzzy Mathematics [06]

Basic concept of Fuzzy Logic, Fuzzy set – Basic definition – Membership function, Operations of fuzzy sets.

[Unit 5] Fuzzy Theory [06]

Fuzzy relations - Fuzzy graphs - Fuzzy analysis – Propositional logic, predictive logic, And Fuzzy Set Theory.

[Unit 6] AI Applications in Power Systems [09]

Application of ANN and Fuzzy logic in Power System
Planning, Operation and control – load forecasting, Unit Commitment, Load Dispatch and Protection.

References:

1. Simon Haykin, "Neural Networks: A Comprehensive Foundation", 2nd Edition, Pearson Education.
2. Zimmermann, H. J., 'Fuzzy Set Theory and Its Applications', 2nd Edition, Kluwer Academic Publishers.
3. El Hawaray "Electrical Power Applications with Fuzzy systems", IEEE Press.
4. Power System Optimisation- D. P. Kothari, J. S. Dhillon, PHI
5. M.Ganesh,"Introduction to fuzzy sets and fuzzy logic" Prentice Hall India.
6. Kelvin Waruicke, Arthur Ekwille, Raj Agarwal, "AI Techniques in Power System", IEE London U.K

