Scheme & Syllabi
ME
(Power Systems)

w.e.f. 2017

Department of Electrical and Instrumentation Engineering
Thapar Institute of Engineering & Technology, Patiala

Electrical & Instrumentation Engineering Department
ME (Power Systems) *w.e.f. 2017*

First Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1	PEE105	Advanced Power Electronics	3	1	2	4.5
2	PEE106	Modelling and Analysis of Power System	3	1	2	4.5
3	PEE107	Power System Transients and Mitigation	3	1	0	3.5
4	PEE108	Static Protective Relaying	3	0	2	4.0
5	PEE109	Power System Dynamics and Stability	3	1	0	3.5
6	PEE205	Intelligent Algorithms in Power Systems	3	1	2	4.5
		Total	**18**	**5**	**8**	**24.5**

Contact hrs./week: 31
Credits First sem : 24.5

Second Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1	PEE206	Power System Operation & Control	3	1	2	4.5
2	PEE207	Power System Planning and Restructuring	3	0	0	3.0
3	PEE208	High Voltage Technology	3	1	2	4.5
4	PEE212	FACTS Controllers and Modelling	3	1	0	3.5
5		Elective-I	3	1	0	3.5
6		Elective–II	3	1	2	4.5
		Total	**18**	**5**	**6**	**23.5**

Contact hrs./week: 29
Credits Second sem: 23.5

Eight weeks Summer Internship in Industry/R&D organization during summer vacations.

Third Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1	PEE 291	Seminar (Internship based)	-	-	-	2.0
2	PEE 391	Seminar (Dissertation based)	-	-	-	4.0
3	PEE394	Project	-	-	-	4.0
4	PEE492	Dissertation (Starts)				-
		Total	**-**	**-**	**-**	**10.0**

Fourth Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEE492	Dissertation				16.0
		Total	**-**	**-**	**-**	**16.0**

Total Credits: 74.0

List of Electives

Elective–I

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEE213	Power Quality Monitoring and Conditioning	3	1	0	3.5
2	PEE216	Digital Control Systems	3	1	0	3.5
3	PEE217	Distribution System Operation and Analysis	3	1	0	3.5
4	PEE322	HVAC and HVDC Transmission Systems	3	1	0	3.5
5	PEE305	Load and Energy Management	3	1	0	3.5
6	PEE306	State Estimation and Supervisory Control	3	1	0	3.5
7	PEE307	Power system operation under Deregulation	3	1	0	3.5
8	PEE309/PEE341	Power Quality and Custom power	3	1	0	3.5

Elective–II

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEE301	Digital Signal Processing and Applications	3	1	2	4.5
2.	PEE302	Electric Drives and Control	3	1	2	4.5
3.	PEE304	Digital Controllers and applications	3	1	2	4.5
4.	PEE343	Renewable Energy Systems	3	1	2	4.5
5.	PMA302	Computational Techniques and Statistical Methods	3	1	2	4.5

PEE109 POWER SYSTEM DYNAMICS AND STABILITY

L	T	P	Cr
3	1	0	3.5

Course objectives: To explain the concept of dynamic model of synchronous machine. To impart knowledge about the concepts of the small signal stability and to discuss the concept of voltage stability and sensitivity analysis.

Dynamic Model of synchronous machine: Concept of synchronously rotating reference frame, two–axis model, Elimination of stator/network transients, one–axis model (flux-decay model), steady state equivalent from dynamic model, electromagnetic and damping torque, accounting the effect of main flux and cross flux saturation, Frequency during transients.

Multi–Machine Simulation: Development of multi-machine dynamic models, Stator Algebraic Equations, Network Equations, Simplification of Two–axis model, Reduced–order multi–machine models: Flux–decay model, Structure–preserving classical model, Internal–node model, Numerical solution of multi-machine dynamic model.

Small–Signal Stability: Introduction, linearization techniques, Participation factors, Studies on parametric effects: Effect of loading, Effect of gain constants and type of load, Hopf bifurcation, Electromechanical oscillatory modes, Power system stabilizers: Basic approach, Derivation of K1–K6 constants, Synchronizing and damping torques, Power system stabilizer design.

Energy function methods: Introduction, Physical and mathematical aspects, Lyapunov's method, Modeling issues, Energy function formulation, Potential energy boundary surface (PEBS), Energy function for single–machine infinite–bus system, Equal–area criteria and energy function, Multi–machine PEBS.

Voltage Stability: Concept of active/reactive power flow transmission using elementary models, Difficulties with reactive power transmission, concept of PV and QV curves, Numerical bifurcation techniques, Detection of bifurcation point, continuation power flow, sensitivity analysis for voltage stability.

Minor Project (if any): Simulation studies of Dynamic and Transient stability analysis, Simulation of sensitivity analysis of voltage stability of Synchronous machine.

Course Learning Outcomes: On the completion of the course the student may be able to

- To develop the dynamic model of synchronous machine
- To simulate multi-machine dynamic model
- To realise the concepts of small signal stability.
- To investigate the various aspects of energy function methods.
- To carry out the sensitivity analysis of the power system.

Recommended Books

1. *Annderson, P.M, Foud, A. A., Power System Control and Stability, IEEE Computer Society Press (2002).*
2. *Kimbark, E., Power System Stability, Vol. I, II & III, IEEE Computer Society Press (2004).*
3. *Kundur, P., Power System Stability and Control, McGraw–Hill (2006).*
4. *Sauer, P.W. and Pai, M.A., Power System Dynamics & Stability, Pearson Education (2005).*
5. *Taylor, C.W., Power System Voltage Stability, McGraw–Hill (2003).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE105 ADVANCED POWER ELECTRONICS

L	T	P	Cr
3	1	2	4.5

Course Objectives: To impart knowledge about the physics of device operation, static and dynamic characteristics, ratings, protection, operating limitations and safe operating area , to discuss the design issues of drive circuits and their usage. PWM schemes, understanding of inverters and cyclo-converters, DC-DC converters and resonant inverters and their analysis with R, RL, RLE type of loads

Introduction: Power Flow Control by Switches, Attributes of a Practical Switch, Physics of device operation, static/ dynamic switching characteristics, ratings, protection, operating limitations and safe operating area.

Gate and Drive Circuits: Design Consideration, De-coupled drive circuits, electrically isolated driver circuits, Cascade connected drive circuits, Protection in drive circuits, Heat sink Design

PWM Inverter Modulation Strategies: Single and multiple PWM, Sinusoidal PWM (SPWM), Modified SPWM, Space vector modulation and hysteresis band current control PWM techniques. Line frequency inductor design, High frequency transformer design for power converters.

Power Converters : H-bridge configuration of converter, $120^0/180^0$ mode of operation of three phase inverters, Three phase Step wave inverter circuits, Three phase PWM controlled inverter circuits, Multilevel inverter, Matrix converters, Phase Controlled and Envelope Cyclo-converters.

DC-DC Converter: Buck Converter, Boost Converter, Buck-Boost Converter; Switch Mode Converter Power Supplies: Push-Pull Converter, Full-Bridge Converter, Forward Converter, Fly-back Converter; Resonant DC-DC converters: Basic circuit concepts, Analysis and design of Series Resonant Converter (SRC), Parallel Resonant Converter (PRC) and Series-Parallel Resonant Converter (SPRC) Circuits, PWM resonant converters: Zero-Voltage and Zero-Current Resonant Converter, reduction in THD and power factor improvement, Industrial applications

Laboratory Work: Device characteristics, Gate Drive Circuits, PWM signal Generation, DC-DC Converter, Three phase full converter, Voltage Source Inverter, Half and Full wave Cyclo-converter, Simulation of Power Converters and harmonic analysis.

Minor Project: Harmonic analysis of power converters with continuous and discontinuous operating modes, Investigation of performance of power converters with PWM firing scheme

Course Learning Outcome: On the completion of the course, the student will be able

- To identify the power semiconductor devices and its utilisation
- To design the Gate and base drive circuits
- To develop skills to utilize the different PWM schemes
- To validate the performance of different types of power converters
- To select the power converter for variety of applications

Recommended Books

1. *Mohan, N., Undeland, T.M. and Robbins, W. P., Power Electronics: Converter Applications and Design, John Wiley and Sons (2007).*
2. *Rashid, M.H., Power Electronics Circuits, Devices and Applications, Prentice-Hall of India Private Limited (2006).*
3. *Sen, P.C., Power Electronics, Tata McGraw-Hill Publishing Company (1996).*
4. *Philip T. Krein, Elements of Power Electronics, Oxford university Press (2008)*
5. *Bose B.K., Power Electronics & AC Drives, Prentice Hall Englewood cliffs, NJ, (1986)*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
4.	MST	25
5.	EST	35
6.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE106 MODELLING AND ANALYSIS OF POWER SYSTEM

L	T	P	Cr
3	1	2	4.5

Course Objectives: To impart learning of mathematical models of power system components, power system analysis techniques and optimal power flow issues and concept of unit commitment, economic thermal and hydro-thermal scheduling. To demonstrate the performance and modeling of power system during short circuit studies and the important of contingency analysis in power system security.

Static Model of Power System components: Generator, single circuit & multi-circuit transmission line, regulating & phase shifting transformer, VAr compensators and Loads for balanced and unbalanced conditions. Formulation of Admittance and Impedance Matrices for balanced and unbalanced conditions, their modifications, Sparcity and Optimal ordering.

Power Flow Analysis: Review of power flow problem, power flow analysis methods, power flow using Newton Raphson method, power flow for unbalanced system.

Optimal Power Flow: Significance of optimal power flow (OPF), formulation of OPF problems, solution using Gradient based methods.

Short circuit studies: Review of symmetrical components, sequence impedances and networks for power system components, Fault analysis of balanced and unbalanced faults in small and large system. Estimation of short circuit capacity of breakers.

Power System Security: Introduction to power system contingencies, Factors affecting security, Contingency analysis, Network sensitivity using DC and AC load flow methods, correcting the generation dispatch.

Laboratory Work: Load–Flow Studies for balanced and unbalanced system, Sparsity handling techniques, Fault analysis, Single objective optimal power flow, contingency analysis

Minor Project: Simulation of Load flow studies of IEEE bus systems, simulation of Optimal power Flow on 14/30 bus system

Course Learning Outcome: On the completion of the course, the student will be able

- To develop with the mathematical model of power system components
- To carry out power system analysis techniques and optimal power flow.
- To handle issues related to unit commitment, economic thermal and hydro-thermal scheduling.
- To analyse the behavior of system during short circuit and the important of contingency analysis.
- To validate the power system security through simulations.

Recommended Books

1. *Grainger, J.D., Power System Analysis, Tata McGraw–Hill Publishing Company (2008).*
2. *Kusic, C.L., Computer Aided Power System Analysis, TMH Publishing Company (2001).*
3. *Pai , M. A., Computer Techniques in Power System Analysis, TMH Publishing Company (2003).*
4. *Stagg, G. W. & El Abiad, A. H., Computer Methods in Power System Analysis, McGraw–Hill (1983).*
5. *Anderson P.M., Analysis of Faulted Power System, IOWA State University Press, New York.*
6. *Singh L.P., Advanced power system analysis and dynamics, 3rd Ed., Wiley Eastern, New Delhi, (2012)*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
7.	MST	25
8.	EST	35
9.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE107 POWER SYSTEMS TRANSIENTS AND MITIGATION

L	T	P	Cr
3	1	0	3.5

Course Objectives: To give overview of nature of power system transients , the concept of travelling waves, to explain the phenomenon of switching surges and lightning surges and its modelling , To impart knowledge of the criteria of insulation coordination and its standards

Introduction to Fast Transients: Origin and nature of power system transients, Traveling waves on transmission system, The line equation, the shape attenuation and distortion of waves, Reflection of traveling waves, Successive reflections, Traveling waves on multi conductor systems, Transition points on multi conductor circuits.

Lightning: Charge formation, Mechanism of lightning stroke, Mathematical model of lightning stroke.

Theory of Grounds Wires: Stoke to a tower, Effect of reflection up and down the tower, The counterpoise.

Switching Surges: Normal frequency effects, High charging currents, Cancellation waves, Recovery voltage, Restricting phenomena, Protection of transmission systems against surge.

Insulation Coordination : Insulation coordination procedures (IEC) for high voltage systems: Design criteria, Classification of overvoltages, Insulation design for switching, Lightning and temporary overvoltages, Pollution, application of arresters for protection of lines and stations, Statistical methods of insulation coordination, Risk of failure, Test prescriptions. Insulation coordination procedures (IEC) for low voltage systems: Representative overvoltages, Selection of clearance and creepage distances, Macro and micro environments, Testing techniques, Transient (switching and lightning) voltage surge suppression in industrial and commercial electrical installations, Protection of electronic devices.

Course Learning Outcome: On the completion of the course, the student will be able

- To understand the causes and effects of switching and lightning surges
- To identify the protection schemes of power system equipment from overvoltages like ground wires, surge absorbers and arrestors.
- To design of insulation of power system components
- To carry out the insulation testing procedures

Recommended Books

1. *Greenwood, A., Electrical Transients in Power Systems, Wiley Inter-Sscience (1991).*
2. *Bewley, L..V., Travelling Waves on Transmission System, Power Publications Inc. (1993).*
3. *Rudenterg, R., Electric Stroke Waves in Power Systems, Harvard University Press (1998).*
4. *Gonen, T., Electric Power Transmission System Engineering: Analysis and Design, John Wiley and Sons (1997).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE108 STATIC PROTECTIVE RELAYING

L	T	P	Cr
3	0	2	4.0

Course Objectives: To give overview of power system protection requirements. Digital protection using different types of static relays, its application to modern power system and apparatus and to understand the operation of relays using microcontrollers

Introduction: Overview of protection systems and relaying, concept of digital simulation of relaying signals. Current and Voltage Transducers: their features and characteristics under steady state and transient conditions.

Static Relays: Overview of Electromechanical Relays and their operating characteristics, Static Relays and comparison with electromechanical relays, Mathematical theory of relay as a comparator, Operating principles and characteristics of various static relays like overcurrent relay, Distance relay, Switched distance relay, Directional relay, Poly-phase relay, Frequency relay.

Digital Protection of Bus-bar, Transformer and Generator Systems*:* High impedance and low impedance differential protection schemes, Protection schemes for bus–bar, transformer and generator

Digital Protection of Transmission Line Systems: Distance protection system and characteristics, Differential line protection, Phase comparison line protection, Use of line carrier and communication links.

Digital Protection Scheme for Distribution Systems: Protection criteria for distribution system, Features of directional and non-directional protection schemes for distribution system

Relay Setting and coordination: Coordination of overcurrent, Distance and directional relay, Integrated relaying operation in power system. Real–time considerations, Adaptive relaying, Integrated substation protection and control, Introduction to IEC protocols.

Microcontroller/DSP based protection: Signal conditioning, Sampling and analog to digital conversion, Hardware realization– Microcontroller/DSP based, Relaying algorithms, Software considerations, Applications for Digital protection schemes for transmission lines, Generators and transformers,

Laboratory Work: Experiments on differential realy, overcurrent relay, differential prptection for generator, transformer and transmission lines, Simulation of protection schemes using SIMULINK, Operation and control of of relays through microprocessor/microcontrollers.

Course Learning Outcome: On the completion of the course, the student will be able

- **To k**nowing static relays and its types.
- To analyse the digital protection schemes for transmission lines, generators and transformers.
- To simulate the protection schemes for radial snd mesh connected systems.
- To realize relaying algorithms with different relay settings and on microcontrollers or microprocessors.

Recommended Books

1. Johns, A.T. and Salman, S.K., Digital Protection for Power Systems, IEE Power Series (1995).

2. Rao, T.S.M., Power System Protection: Static Relays, TMH Publishing Company (2008).

3. Wu, Q.H., Lu, Z., Ji, T.Y., Protective Relaying for Power Systems using Mathematical Morphology, Springer (2009).

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	40
3.	Sessionals (May include ssignments/Projects/Tutorials/Quizes etc.)	35

PEE205 INTELLIEGENT ALGORITHMS IN POWER SYSTEMS

L	T	P	Cr
3	1	2	4.5

Course Objectives: To impart knowledge about basic significance of artificial intelligence in the area of decision making, recognition, similarity matching etc.To explain the concept of artificial neural network and its models, various learning algorithms in supervised and unsupervised mode, concept of fuzzy logic and fuzzy logic system, concept of genetic algorithms and genetic operator, to understand the hybrid structure .

Overview: Concepts of artificial intelligence (AI) and optimization, Introduction of various AI techniques, features and advantages in comparison to conventional methods, applications in electrical systems.

Artificial Neural Network: Review of ANN and learning processes, Learning algorithms, Transforming static neural network into dynamic, Neuronal filters, Supervised learning as an optimization method, Temporal back–propagation algorithm, neurodynamical model, Application of Hopfield neural network for constrained and unconstrained optimization, Stochastic machines, recurrent network architectures,

Fuzzy Logic: Review of fuzzy sets and fuzzy systems, Development of membership function, Fuzzy measures, LR Fuzzy numbers, Fuzzy Bayesian decision making, Fuzzy system design and simulation, Fuzzy optimization, Solution of linear system under fuzzy environment, Multi–input, Multi–output system, Multi–objective decision making.

Evolutionary computation: Review of evolutionary computation techniques, algorithms and various operators, Mapping unconstrained and constrained optimization problems, Evolutionary programming

Multi-objective optimization: Comparison with single objective optimization, Concept of dominance, Non–dominated sorting, Multi-objective optimization using genetic algorithm.

Integrated Systems: Introduction to integrating systems like fuzzification of neural network, Neural–fuzzy controller, GA based fuzzy classification, GA based parameter learning of neural network.

AI Applications in Power Systems: Case studies such as Economic load dispatch, Load forecasting, Optimal power flow, transient stability and power system stabilizers, Hydro–thermal scheduling, voltage control, Protection system

Laboratory Work: Understanding the Fuzzy, Neural network and GA concepts through programming, MATLAB Tool boxes, Fuzzy system applications, Power system stabilizer, Neural network models and learning, Constrained optimization using neural network like Economic Dispatch, Implementing binary and real valued GA.

Minor Project: Implementation of Intelligent technique for economic load dispatch, speed control of induction motor, Load forecasting using Fuzzy logic

Course Learning Outcome: On the completion of the course, the student will be able

- To develop the neuron models with analog and discrete inputs, network architectures and training of network through various learning algorithms in supervised and unsupervised mode.
- To implement the concept of fuzzy logic concept and its implementation in controller applications
- To demonstrate the concept of evolutionary computation using Genetic algorithm for decision making problems.

Recommended Books

1. *Ross, J. T., Fuzzy Logic with Engineering Applications, McGraw–Hill (1995).*
2. *S. Haykin, Neural Network : A Comprehensive Foundation, Pearson Education (2003).*
3. *Lin, C., Lee, G., Neural Fuzzy Systems, Prentice Hall International Inc. (2000)*
4. *Deb, K., Multiobjective Optimization using Evolutionary Algorithms, John Wiley and Sons (2002).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	35
3.	Sessionals (May include ssignments/Projects/Tutorials/Quizes etc.)	40

PEE206 POWER SYSTEM OPERATION & CONTROL

L	T	P	Cr
3	1	2	4.5

Course Objectives: To impart learning about the power system controls namely load-frequency and AVR control for both single-machine infinite bus system and multi-machine systems and to learn optimal system operation through optimal generation dispatch, unit commitment, hydro-thermal scheduling and pumped storage plant scheduling and their implementation through various classical methods.

Load Frequency Control: Introduction, Modelling of ALFC control loop, biased control, concept of multi-area control, tie line bias control, Mathematical models of various turbine-governor systems, stability analysis of single area and multi area systems, transient stability analysis of multi-machine system

AVR Control: Mathematical model of AVR control loop, modeling of various excitation systems, stability analysis of AVR systems, Lag-Lead compensation, cross coupling between AVR and ALFC control loops. Concept of AVR in multi-machine system, concept of reactive power and voltage dependency, voltage stability analysis of single machine infinite bus system.

Optimal generation dispatch: Input Output characteristics of a power generation units, Optimum generation allocation of thermal units with and without losses, Derivation of transmission loss formula, Reactive power dispatch, Environmental economic dispatch, optimal dispatch of hydro units

Hydro–Thermal Coordination: Advantages of coordination, Optimal scheduling of hydrothermal system, short term, long term and stochastic hydro-thermal scheduling, Combined working of Runoff river plant with steam plant, Multi-reservoir plant, Pumped storage hydro plants.

Unit Commitment: Optimal Unit commitment, Solution to unit commitment by dynamic programming, effect of start-up and shut down time/cost, Optimal unit commitment with security.

Laboratory Work: Implementation of Load frequency control and AVR control in single area system, Optimal generation dispatch, Hydrothermal scheduling, Unit commitment.

Course Learning Outcome: On the completion of the course, the student will be able

- To understand the power system controls namely load-frequency and AVR control for both single-machine infinite bus system and multimachine systems,
- To formulate problems of the optimal system operation through optimal generation dispatch, unit commitment, hydro-thermal scheduling and pumped storage plant scheduling
- To implement the optimal power system operation problems through various classical methods.
- To analyse the results of optimal dispatch and scheduling

Recommended Books

1. *Wood, A.J. and Wollenberg, B.F., Power Generation, Operation and Control, John Wiley and Sons (2003*
2. *Kothari, D.P., Dhillon J.S. Power system Optimisation, 2nd Ed., PHI, (2011)*
3. *Elgerd O.I., Electric Energy System Theory- An Introduction, McGraw-Hill* ***, (1996)***
4. *P. Kundur, “ Power System Stability & Control” Tata McGraw Hill, (2007)*
5. *M.E. El-Hawary, G.S. Christensen, “ Optimal Economic Operation of Electric Power Systems”, Academic Press (1979)*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE207 POWER SYSTEM PLANNING & RESTRUCTURING

L	T	P	Cr
3	0	0	3.5

Course Objectives: To explore objectives of national and regional planning of electricity, criteria of generation planning, solution methodologies of forecasting, optimal power system expansion and its planning, and to learn about unintegrated and bundled power systems

Introduction of Power Planning: Objectives, National and Regional Planning, Long and short term planning, Structure of Power System, Planning tools, Electricity Regulation, Load forecasting: Characteristics of loads, Methodology of forecasting, Energy forecasting, Peak demand forecasting, Total forecasting, Annual and monthly peak demand forecasting.

Generation Planning: Introduction, Integrated power generation cogeneration/captive power, Power pooling and power trading.

Optimal Power System Expansion Planning: Introduction, Formulation of least cost optimization problem incorporating the capital, Operating and maintenance cost of candidate plants of different types (Thermal, Hydro, Nuclear, Non-conventional etc.) and minimum assured reliability constraint: Optimization techniques for solution by programming.

Transmission and Distribution Planning: Introduction, Transmission planning under uncertainty, Power sector finance, Financial planning, Private participation Rural Electrification investment, Concept of Rational tariffs, Environmental effects, The green house effect, Technological impacts.

Restructuring: Operation of vertically integrated power systems, Models and examples of deregulated operation, Independent power producers, Optimal dispatch based on offers and bids, Unit commitment, Power wheeling, Transmission pricing and congestion, Allocation of spinning reserve, Demand side bidding, Pricing schemes, Competitive electricity markets.

Minor Project: Prepare a report of risk assessment and econometric analysis of generation planning

Course Learning Outcome: On the completion of the course, the student will be able

- To understand the concept and significance of power system restructuring and integrated generation.
- To formulate the power system generation expansion asa an optimization problem with cost, emission and reliability as major constraints
- To qualify the technological impacts of transmission & distribution planning under uncertainty factors
- To conceptualize the impact of bidding and pricing in competitive electricity markets.

Recommended Books

1. *X. Wang, J.r. McDonald, Modern Power System Planning ,McGraw Hill Int. Ed. (1994).*
2. *Sullivan, R.L., Power System Planning, Heber Hill (1977).*
3. *Lai, L.L., Power System Restructuring and Deregulation: Trading Performance and Information Technology, John Wiley and Sons (2001).*
4. *National Power System planning Commission Annual Reports, GOI, India*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	50
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	20

PEE212 FACTS CONTROLLERS AND MODELLING

L	T	P	Cr
3	1	0	3.5

Course Objectives: To learn the concept of power flow control through various power electronic controllers including state of art FACTS controllers, operational aspects and their capabilities and their integration in power flow analysis, FACTS controllers and to learn the effectiveness of FACTS controllers in distribution system for harmonic mitigation etc.

Overview: Concept of reactive power compensation, Review of series and shunt compensation, Concepts of transient stability and voltage stability, Power system oscillations.

Shunt Compensators: Mid point voltage regulation, Method of controlled VAr generation, principle of operation, Control and characteristics of SVC and STATCOM, Multi-control functional model of STATCOM for power flow analysis, Implementation of STATCOM models in Newton power flow, STATCOM in optimal power flow (OPF), STATCOM in distribution system (DSTATCOM), DSTATCOM performance in various modes including harmonic mitigation.

Series Compensators : Series compensation and voltage stability, Variable impedance type series compensators (TCSC) and switching converter type series converter (SSSC), Configurations, Control and characteristics, General applications, Modelling of multi–control functional model of SSSC in power flow analysis, Implemetation of SSC models in Newton power flow, SSSC in OPF, Dynamic Voltage Restorer (DVR) in Distribution System, Subsynchronous Resonance Problem, NGH Scheme.

Unified Power Flow Controllers : Objectives and principle of operation of voltage and phase angle regulations, Static phase shifter and its operating characteristics**,** Unified Power Flow Controller (UPFC) control and characteristics, UPFC as generalised SSSC, Modelling of UPFC for power flow and OPF studies, Implementing UPFC in Newton power flow, Power oscillations control with UPFC.

Interline power flow controller: Principle of operation, Control and characteristics, Model of IPFC for power flow and optimum power flow studies.

Course Learning Outcome: On the completion of the course, the student will be able

- To understand the power system control through various power electronic controllers including state of art FACTS controllers.
- To analyse the operational aspects and their effectiveness in transient stability enhancement,
- To assess the issues of damping to power system oscillations, real and reactive power control capability in power system
- To learn the integration in power flow analysis and their effectiveness in distribution system for harmonic mitigation etc.

Recommended Books

1. *Song, Y.H. and Johns, A.T., Flexible AC Transmission Systems, IEEE Press (1999).*
2. *Hingorani, N.G. and Gyragyi, L., Understanding FACTS (Concepts and Technology of Flexible AC Transmission System), Standard Publishers & Distributors (2001).*
3. *Mathur, R.M. and Verma, R.K., Thyristor based FACTS controllers for Electrical Transmission Systems, IEEE Press (2002).*
4. *Zhang, X. P., Rehtanz, C. and Pal, B., Flexible AC Transmission Systems: Modelling and Control, Springer (2006).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE213 POWER QUALITY MONITORING AND CONDITIONING

L	T	P	Cr
3	1	0	3.5

Course Objectives: To impart knowledge about the aspects of power quality in distribution system and various indices. sources of harmonics, various power quality problems, remedial measures to power quality problems through filtering and static controller, to discuss the advanced multi-level converters .

Overview: Sources of pollution and regulations, Various power quality problems, Transmission problems and needs, The emergence of FACTS, FACTS controller and consideration.

Voltage Sag and Swell: The voltage sag and voltage swell, causes of voltage sag and swell, Indices to classify voltage sag, The countermeasures.

Monitoring of Power Quality: Monitoring essentials, reliability indices, Power quality measuring equipment, Current industry trends, Fourier series, Fourier transform, Wavelet transform. **Harmonics:** Effects–within the power system, Interference with communication Harmonic measurements, Harmonic elimination, Harmonic distortion due to various sources, Effects of harmonic distortion, THD calculation

Power Supply and Applications: Analysis, design and control of SMPS, UPS on line and off line, Power supplies in telecommunication and auto–mobiles, Linear series and shunt voltage regulators, Switching regulators, High frequency induction heating, Dielectric heating, Microwave heating, Electronic ballast, High power factor electronic ballast and applications.

Multi–Level Converters and Control: Modelling and analysis of advance static VAr compensation, Multi level inverters, Harmonic elimination method, ASVC structure, Power converter control using state space average models, SMC, Fuzzy logic control.

Filters: Passive and active filters for harmonic and reactive power compensation in two wire, Three wire and four wire AC systems, Harmonics standard, Power quality, Surge suppressors, Compensation of arc furnaces and traction loads.

Static VAR compensator (SVC): Types of SVC characteristics of ideal and realistic SVC their operation, Composite characteristics, Modelling of SVC, Six pulse TCR, Flexible AC Transmission Systems, Comparison of STATCOM and SVC, Static Voltage and phase angle regulators: TCVR and TCPAR, Combine compensator, UPFC (Unified Power Flow), IPFC (Interline power flow controller), and their applications.

Course Learning Outcome: On the completion of the course, the student will be able

- To learn aspects of power quality in distribution system, sources of harmonics
- To identify the power quality problems
- To acquire knowledge about the measures through filtering and static controller,
- To know about the harmonic mitigation through multi-level converters

Recommended Books

1. *Bollen, M.H.J., Power Quality Problems: Voltage Sag and Interruptions, IEEE Press (2007).*
2. *Bollen, M.H.J., Understanding Power Quality and Voltage Sag, IEEE Press (2006).*
3. *Ghosh, A. and Ledwich, G., Power Quality Enhancement using Custom Power Devices, Kluwer Academic Publishers (2002).*
4. *Hingorani, N.G., Understanding FACTS: Concepts and Technology, IEEE Computer Society Press (1995).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE216 DIGITAL CONTROL SYSTEMS

L	T	P	Cr
3	1	0	3.5

Course Objectives: To review the discrete control system and their mathematical modeling and impart learning about s-plane and z-plane transformations, To understand the state diagrams and their analysis, To know about the stability criteria in control systems

Introduction: Review of discrete data control system, Signal conversion and processing, mathematical modeling of convolution integral and sampling process, S-plane properties

z-Transform: Definition, relation between Laplace and z-transform, s-plane and z-plane, inverse z-transform, z-transform theorems, difference equation solutions, delayed and modified z-transform.

Analysis of Digital Control Systems: Transfer functions, block diagrams and signal flow graph, closed loop system characteristic equation, multi-rate discrete data system, state equations and state transition equations, Eigen values and eigen-vector, state diagram and decomposition of discrete data transfer functions, controllability and observability.

Stability Analysis: Steady state error analysis of digital control systems, Root locus for digital control systems, effect of addition of poles and zeros, polar plot of GH(z), Jury's stability test, Nyquist stability criteria, Lyapunov stability criteria, concept of relative stability

Design of discrete data control system: Digital PID controller, design in z-plane using Root-locus, Design of robust control systems, Time optimal control with energy constraints. Principle of optimality and dynamic programming, adaptive control systems.

.**Course Learning Outcome:** On the completion of the course, the student will be able

- To learn about the discrete digital control system
- To perform the stability analysis using various techniques,
- To design and develop of PID controller

Recommended Books

1. *Kuo B.C., Digital Control Systems, Oxford univ. press, 2nd ed., (2009)*
2. *Ogatta, K., Discrete time control systems, Prentice Hall, Int. ed., (1987)*
3. *Franklin G.F., Powell J.D., & Workman M.L., Digital Control of Dynamic Systems, 2nd ed., Addison-Wesley, Reading, (1990)*
4. *Gopal M., Modern Control System Theory, Wiley Eastern 2nd ed., (1993)*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE217 DISTRIBUTION SYSTEM OPERATION AND ANALYSIS

L	T	P	Cr
3	1	0	3.5

Course Objectives: To know about the distribution system and its planning, To learn about types of load and their characteristics, to impart learning about the design of operational area of distribution system

Introduction To Power System Planning And Automation: Introduction, Distribution system planning, Factors affecting system planning, present planning techniques, planning models, future trends in planning, systems approach, distribution automation

Load Characteristic: Basic definition, relation between load and loss factors, maximum diversified demand, load forecasting, Load management.

System Planning: Planning process, planning criteria, system developers, dispersed generation, distribution systems, economics and finance, mapping.

Design And Operation: Engineering design, operation criteria, substation and feeder, voltage control, harmonics, load variations, system losses, energy management.

Distribution System Voltage Regulation: Quality of Service and Voltage Standards, Voltage Control, Line Drop Compensation, Distribution capacitor automation, Voltage fluctuations.

Distribution Automation: Definitions, communication, sensors, SCADA.

Optimization: Introduction, costing of schemes, typical network configurations, planning terms, network cost modeling, synthesis of optimum line network.

Distribution System Protection: Objective of distribution system protection, coordination of protective devices, fuse to fuse co-ordination, recloser to recloser coordination, recloser to fuse coordination, recloser to substation transformer high side fuse coordination, fuse to circuit breaker coordination, recloser to circuit breaker coordination, high impedance faults, lightning protection.

.**Course Learning Outcome:** On the completion of the course, the student will be able

- To learn the operational aspects of distribution system
- To familiarization with distribution system configurations, loads, power flow,
- To analyse the effect of reconfigurations
- To learn about the protection in distribution systems.

Recommended Books

1. *Gonen, Turan, Electric Power Distribution System Engineering, CRC PRESS (2012), Third Indian Reprint*
2. *Pabla , A S. , Electric Power Distribution, TMH (2011), 6th Edition.*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PMA COMPUTATIONAL TECHNIQUES AND STATISTICAL METHODS

L	T	P	Cr
3	1	2	4.5

Course Objectives: To explain the necessary conditions of convex and concave optimisation problems, To describe various types of conventional solution techniques applied to optimisation problems, To impart knowledge about the probability concepts, To demonstrate the ANOVA process

Introduction: Review of Linear Programming concepts.

Unconstrained Problems: First-Order Necessary Conditions, Second-Order Conditions Convex and Concave Functions, Minimization and Maximization of Convex Functions Zero-Order Conditions, Global Convergence of Descent Algorithms, Speed of Convergence.

Basic Descent Methods: Fibonacci and Golden Section Search, Line Search by Curve fitting, Global Convergence of Curve Fitting, Closedness of Line Search Algorithms, Inaccurate Line Search, The Method of Steepest Descent, Newton's Method, Coordinate Descent Methods, Spacer Steps.

Conjugate Direction Methods: Conjugate Directions, Descent Properties of the Conjugate Direction Method, The Conjugate Gradient Method, The CûG Method as an Optimal Process, The Partial Conjugate Gradient Method, Extension to Nonquadratic Problems,

Quasi-Newton Methods: Modified Newton Method, Construction of the Inverse, DavidonûFletcherûPowell Method, The Broyden Family, Convergence Properties, Scaling, Memoryless Quasi-Newton Methods, Combination of Steepest Descent and Newton's Method.

Constrained optimization: Kuhn-Tucker conditions, Quadratic programming problems, Algorithm for constrained optimization, Gradient projection method, Dual of quadratic programming problems**.**

Review of Probability: Appraisal of axiomatic approach of probability, Conditional probability, Baye's rule, Conditional distributions, and conditional expectations.

Markov chains: Basics of markov chains, Finite state space, Markov chains, Transition and stationary markov chains. Continuous time markov process: continuous time branching processes, Kolmogorov, Forward and backward equations, Pure birth, Pure death, Birth and death process.

Analysis of variance: One Way Classification: ANOVA for fixed effect model, ANOVA for Random Effect Model, Two-way Classification (one observation per cell): ANOVA for fixed effect model, ANOVA for Random Effect Model.

Design of Experiments: Completely Randomised Design, Randomised Block Design, Latin Square Design, their statistical analysis and variance of estimates, Analysis of Covariance.

.**Course Learning Outcome:** On the completion of the course, the student will be able

- To apply conventional techniques of direct search to solve un constrained optimisation problems
- To solve constrined optimisation problems.
- To apply ANOVA test to assess the degree of variance,
- To analyse design of experiments through variance and covariance estimates
- To apply the concept of proabilibity to understand the frequency of occurrence and adequacy estimate.

Recommended Books

1. *Luenberger D.G., Linear and Nonlinear Programming, Addison Wesley (2003).*
2. *Fletcher R., Practical methods of Optimization, John Wiley (1980).*
3. *Taha H.A., Operation research- An Introduction, PHI (2007).*
4. *Populis,A., Random Variables and Stochastic Processes, Tata McGraw Hill (2002).*
5. *Montgomery, Introduction to Statistical Quality Control, John Wiley and Sons (2005).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	35

PEE322 HVAC AND HVDC TRANSMISSION SYSTEMS

L	T	P	Cr
3	1	0	3.5

Course Objectives: To know modern transmission systems using HVDC and HVAC, to understand study static VAr system, corona and radio & TV interference and to learn design filters for harmonics reduction.

Overview: Comparison of EHVAC and HVDC transmission, Description of DC transmission systems, Modern trends in AC and DC transmission.

HVAC System: Limitations of extra long AC transmission, Voltage profile and voltage gradient of conductor, Electrostatic field of transmission line, Reactive Power planning and control, Traveling and standing waves, EHV cable transmission system.

Static VAr System: Reactive VAr requirements, Static VAr systems, SVC in power systems, Design concepts and analysis for system dynamic performance, Voltage support, Damping and reactive support.

HVDC System: Converter configurations and their characteristics, DC link control, Converter control characteristics, Monopolar operation, Converter with and without overlap, Smoothing reactors, Transients in DC line, Converter faults and protection, HVDC breakers.

Corona and Interference: Corona and corona loss due to HVAC and HVDC, Radio and TV interference due to HVAC and HVDC systems, Methods to reduce noise, Radio and TV interference.

Harmonic Filters: Generation of harmonics, Design of AC filters, DC filters.

Power Flow Analysis in AC/DC Systems: Modelling, Solution of DC load flow, Solution techniques of AC/DC power flow equations, Parallel operation of HVDC/AC systems, Multi terminal systems.

Course Learning Outcome: On the completion of the course, the student will be able

- To learn HVAC and HVDC transmission systems.
- To analyse system dynamic performance and reactive power requirements.
- To know about corona and radio & TV interference.
- To design filters for reduction of harmonics.
- To solve power flow equations.

Recommended Books

1. *Arrillaga, J., HVDC Transmission, IEE Press (2007).*
2. *Arrillaga, J. and Smith, B.C., AC to DC Power System Analysis, IEE Press (2008).*
3. *Begamudre, R..D., EHVAC Transmission Engineering, New Age International (P) Limited, Publishers (2006).*
4. *Edwart, K., Direct Current Transmission (Vol. 1), John Wiley and Sons (2008).*
5. *Padiyar, K.R., HVDC Power Transmission Systems, New Age International (P) Limited, Publishers (2008).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE301 DIGITAL SIGNAL PROCESSING AND APPLICATION

L	T	P	Cr
3	1	2	4.5

Course Objectives: To introduce with concept of continuous and discrete signals, Frequency analysis of signals, design of digital filters , to explain z-transform and FFT transform

Overview: Concept of frequency in continuous and discrete time signals, A–D Conversion process, Sampling Theorem, Introduction and classification of discrete time signals and systems, Analysis of discrete linear time-invariant (LTI) systems, Convolution and correlation of discrete time signals, Implementation of discrete time systems.

Z-Transform: Z-Transform and inverse z-transform, rational z-transform, Analysis of Linear Time Invariant (LTI) systems in z-domain.

Frequency Analysis of Signals and System: Frequency analysis of continuous and discrete time signals, Fourier series and Fourier Transform for discrete and continuous periodic and non periodic signals.

Discrete Fourier Transform: Frequency domain sampling, Discrete Fourier Transform (DFT), Linear filtering methods based on DFT, Frequency analysis of signals using DFT, Fast Fourier Transform (FFT), FFT algorithms, Methods and Applications of FFT algorithms.

Digital Filter Design: Digital filter, filter design, Infinite Impulse Filter (IIR), finite Impulse filters (FIR)

Multirate Signal Processing: Decimation and Interpolation, Sample rate conversion by Integer and Non-Integer factors.

Random Signals: Random variables, random process, auto-correlation functions, power spectrum density, filtering random signals, window function, wavelet transform, spectrum analysis of random signals.

Applications to Power Systems : DSP applications to power systems such as measurement of frequency, measurement of harmonic level, harmonic analysis, static and digital relays, digital protection, power metering, magnetic field measurement.

Laboratory Work : Determination of Z, Fourier transform, Design of FIR and IIR Filters, Realization of Prediction, equalizer and compression algorithms, use of wavelet transform,

Course Learning Outcome: On the completion of the course, the student will be able

- To learn to apply z-transform and FFT analysis
- To analyse continuous and discrete signals in frequency domain.
- To implement the concepts for measurement of frequency, harmonic level etc.
- To design digital filters for reduction of noise signals
- To apply concepts of DSP to power system protection for measurement of signals.

Recommended Books

1. *Proakis, J.G., and Manolakis D.G., Digital Signal Processing, Prentice Hall of India Private Limited, (1996).*
2. *Rabiner, C.R., and Gold, B., Theory and Applications of Digital Signal Processing, Prentice Hall of India Private Limited (2000).*
3. *Helmut, U., Wilibald, W. and Andrzej, W., Protection Techniques in Electrical Energy Systems, CRC Press, New York (1995).*
4. *Oppenhein, A.V., and Schafer, R.W., Discrete Time Signal Processing, Prentice Hall of India Private Limited (2001).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE302 ELECTRIC DRIVES AND CONTROL

L	T	P	Cr
3	1	2	4.5

Course Objectives: To impart knowledge about fundamentals of Electric drives and control, operational strategies of dc and ac motor drives as per different quadrant operations and to discuss the modeling and control of dc motor drive, ac motor drives and permanent magnet machines.

Review of Drive Concept: Representation of electric drive, Different machines and load characteristics, Four quadrant operation, Equilibrium and steady state stability, , Thermal and overload consideration of electric drives under continuous, Short and intermittent duty cycle.

DC Motor Drive and its Operational Strategies: Dynamic model of machine with armature voltage control only and converters with continuous conduction only; Closed loop control using single (speed) and two loops (speed, current), Implementation using circulating current type three phase dual converter and four quadrant transistorized chopper.

Modelling and Control of DC Drives: State feedback control and sliding mode control of separately–excited DC machine, Modelling and control of separately–excited DC machine in field weakening region and discontinuous converter conduction mode, Control of DC series machine.

Open-loop Dynamic Performance of AC & DC Drives: Starting & reversal time, Energy consumption.

AC Drives and its Operational Strategies: Variable frequency operation of three–phase symmetrical induction machine, Scalar control methods for constant power an constant torque modes, Vector control of induction machine, Methods of field sensing and estimation, Field orientation methods: Implementation of IRFO scheme using current controlled PWM, VSI and implementation of DSFO scheme using CSI, Performance of vector controlled permanent magnet machine.

Control and Estimation of AC Drives: Introduction to speed control of Switched Reluctance Machine, Induction motor drive, Sensorless speed control, Direct torque control and flux observation, Speed control of wound rotor induction motors: Converter based static rotor resistance control, Static scherbius drive using line commutated converter cascade, Analysis and estimation of harmonics and power factor, Vector control of wound rotor induction machine using self-commutated converter cascade and improvement in power factor, Variable speed constant frequency (VSCF) generation.

Control of Permanent Magnet Machine: Permanent magnet synchronous machine, Brushless dc machine, Surface permanent magnet machine and interior.

Laboratory Work: Closed loop current-speed control of AC & DC drives, Variable voltage–variable frequency control, Vector control mechanism, Position control of stepper motor, Direct field orientation of AC drives, Static Scherbius & Kramer method of slip power recovery, PWM based VSI control of induction drive, Converter based Four quadrant operation of DC and AC drives.

Course Learning Outcome: On the completion of the course, the student will be able

- To acquire the knowledge of selection of drives as per practical operational industrial requirement.
- To apply their knowledge to prepare control schemes as per different types of motors used in industries.
- To estimate & solve harmonic and power factor related problems in controlling AC and DC drives.

Recommended Books

1. *Mohan, N., Electric Drives: An Integrative Approach, MNPERE (2001).*
2. *Mohan, N., Advanced Electric Drives: Analysis, Control, and Modeling Using Simulink, MNPERE (2001).*
3. *Krishnan, R., Electric Motor & Drives: Modeling, Analysis & Control, PHI Pvt. Ltd. (2001).*
4. *Miller, T.J.E., Brushless Permanent Magnet and Reluctance Motor Drives, Clarendon Press (1989).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE208 HIGH VOLTAGE TECHNOLOGY

L	T	P	Cr
3	1	2	4.5

Course Objectives: To impart the knowledge about the different causes of high voltage occurrence and the protective devices used. To test and diagnose HV cables. insulation performance of Air and SF_6 and performance of GIS. To discuss the procedure to perform HV test on electrical apparatus.

.**Introduction**: Power Systems Development and High Voltage Engineering; Contents of High Voltage Engineering; Applications of High Voltage Technology.

Traveling Waves: Transient and traveling waves, Effects of Line Terminations, Junction of several lines, Bewley Lattice Diagram, Traveling wave in transformer and generator.

Lightning In Power Systems: Lightning formation, Lightning overvoltages (strike and back flashover), Lightning overvoltages protection devices, Protection system of high buildings.

Switching Overvoltages Types of internal overvoltages, switching overvoltages, Causes of various internal overvoltages, Control of switching overvoltages, EMTP and its applications.

Arresters And Insulation Coordination: Surge arresters (MOA) and its performances, Voltage–Time Characteristics and coordination, Surge arresters selection and location in power systems, Principles of insulation coordination, Statistical and conventional insulation coordination.

High Voltage Cables: Configuration and design features of high voltage cables, Testing of high voltage cables, Diagnostics of high voltage cables.

Air And Sf_6 Breakdown: Fundamental aspects of air and SF6 breakdown, U–curve and gap factor, Spark-over characteristics, SF_6 gas insulation performance.

Gas Insulated Substation: Gas Insulated Substation (GIS) and its importance, Configuration and design features of GIS, Prospects of GIS.

High Voltage Test Of Electrical Apparatus: Nondestructive insulation testing, Destructive insulation testing: AC, DC, and Impulse testing of apparatus, New high voltage measurement technology; Safety in high voltage laboratory.

Laboratory Work: Non- destructive testing, Corona discharge realization, Construction of HVAC and HVDC waves, Thermal tests on Insulation, Impulse wave generation and measurement.

Course Learning Outcome: On the completion of the course, the student will be able

- To understand the causes of occurrence high voltage and travelling waves.
- To knowing the different devices used for protection against high voltage Testing HV cables.
- To learn about characteristics of Air and SF_6 and performance of GIS.

Recommended Books

1. *Khalifa M., High-Voltage Engineering, Theory and Practice, Marcel Dekker Inc (2000).*
2. *Ryan H.M., High voltage engineering and testing, IEEE Press (1994).*
3. Kind, D. and Feser, K, High Voltage Test Techniques, Reed Educational and Professional Publishing Limited (2001).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE304 DIGITAL CONTROLLERS AND APPLICATIONS

L	T	P	Cr
3	1	2	4.5

Course Objectives:

- To introduce with the concepts of DSP processors and its programming concepts
- .To discuss the multiplexed I/O system
- To introduce field programmable arrays with HDL programming concepts
- To discuss the development of power system application around DSp and FPGA

Introduction: C2xx DSP core and code generation, Components of the C2xx DSP core, Mapping external devices to the C2xx core , Peripherals and Peripheral Interface , System configuration registers, Memory, Types of Physical Memory, Memory Addressing Modes, Assembly Programming using C2xx DSP, Instruction Set, Software Tools.

Pin Multiplexing (MUX) and General Purpose I/O: Overview, Multiplexing and General Purpose I/O Control Registers, Introduction to Interrupts, Interrupt Hierarchy, Interrupt Control Registers, Initializing and Servicing Interrupts in Software.

ADC Overview: Operation of the ADC in the DSP, Overview of the Event manager (EV), Event Manager Interrupts, General Purpose (GP) Timers, Compare Units, Capture Units and Quadrature Enclosed Pulse (QEP) Circuitry, General Event Manager Information.

Introduction to Field Programmable Gate Arrays: CPLD vs FPGA: Types of FPGA , Xilinx XC3000 series, Configurable logic Blocks (CLB), Input/Output Block (IOB): Programmable Interconnect Point (PIP), Xilinx 4000 series, HDL programming: Overview of Spartan 3E and Virtex II pro FPGA boards, Case study.

Applications: Switched Mode Power Converters, PWM Inverters, DC motor control, Induction Motor Control.

Laboratory Work: Programming on microcontroller and DSP processors, Applications in Static relaying and protection and motor control

Minor Project: Develop controller using DSP/FPGA

Course Learning Outcome: On the completion of the course, the student will be able

- To develop controller application using DSP programming concept..
- To identify the architecture of processor concepts for I/O.
- To develop spped controller of motor using FPGA.

Recommended Books

1. *Toliyat, H.A. and Campbell, S.G., DSP Based Electro Mechanical Motion Control, CRC Press (2004).*
2. *XC 3000 Series Datasheets (Version 3.1). Xilinx,Inc. (1998).*
3. *XC 4000 Series Datasheets (Version 1.6). Xilinx,Inc. (1999).*
4. *Wolf, W., FPGA Based System Design, Prentice Hall Inc. (2004).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE305 LOAD AND ENERGY MANAGEMENT

L	T	P	Cr
3	1	0	3.5

Course Objectives: To understand the basics of load forecasting and need of forecasting , method of forecasting, To know the steps involved in load management , different tariff structure in our country .impacts of load management and understanding through different case studies, benchmarking in energy management.

Load Forecasting: Classification and characterization of loads, Approaches to load forecasting, Forecasting methodology, Energy forecasting, Peak demand forecasting, Non–weather sensitive forecast and Weather sensitive forecast, Total forecast, Annual and monthly peak demand forecasts, Applications of state estimation to load forecasting.

Load Management: Introduction to Load management, Electric energy production and delivery system structure (EEPDS), Design alternatives for EEPD systems, Communication/control techniques for load management, Tariff structure and load management, principles of macro and microeconomics and energy pricing strategies, Assessing the impacts of load management.

Energy Demand Forecasting: Static and dynamic analysis of energy demand, Elements of energy demand forecasting, Methodologies and models for energy demand forecasting, Techno–economic approach in energy demand forecasting.

Energy auditing, Energy management, Power Pools and Energy Banking

Trends And Case Studies: Energy management strategy, Symbiotic relation between information, Energy models and decision making, Case studies like industrial energy forecasting, Transportation energy forecasting, Residential, Commercial and agricultural energy forecasting

Course Learning Outcome: On the completion of the course, the student will be able

- To be familiar with different load forecasting method used in power system,
- To understand different phase of load management and impacts of load management
- To understand the concept of energy demand and method to satisfy meet the energy demand
- To understand the measurement of energy conservation and its case studies
- To be familiar with ways of saving electricity in different utilities. Different phase of energy audit.
- To understand the role of energy management and energy forecasting

Recommended Books

1. *Martino J., Technological Forecasting for Decision Making", Elsevier Press (1972).*
2. *Gellings C.W. and Penn Well P.E. "Demand Forecasting in the Electric Utility Industry", Fairmount Press (1992).*
3. *Makridakis S., "Forecasting Methods and Applications", John Wiley and Sons (1997).*
4. *Brown, R.G., Smoothing, forecasting and prediction of discrete time series, PHI Int. (1963)*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE306 STATE ESTIMATION AND SUPERVISORY CONTROL

L	T	P	Cr
3	1	0	3.5

Course Objectives: To understand the role of signal conditioning in the field of real time control applications. To investigate the importance of data acquisition system and the need of SCADA system, to familiarize the main features of smart grid and its applications and to understand the concept of micro grid, virtual power plant.

Introduction: Static and Dynamic characteristics, Error analysis; transducers & sensors, Role of instrumentation in monitoring, control & industrial automation

Signal Conditioning: Amplifiers, Multiplexers & dividers, Timer multiplexers, Signal converters, ADC and DAC, Signal conditioning, Digital signal conditioning, Transmission of digital signals, Telemetry methods and errors, PLCC, AM, FM, PAM, PWM, PCM Techniques.

Data Acquisition System: Role of dedicated computers, analog and digital control, Computer systems for real time applications, Distributed and supervisory control, its organization and structure, Centralized, Hierarchical and decentralized control schemes, Man machine interface, Energy management system.

State Estimation: Method of least-squares, State estimation of AC network, Detection and identification of bad measurements, Network observability & pseudo measurements, multi-area state estimation, forecast-aided state estimation. Wide area monitoring systems.

Real Time Control Applications: Conditioning and acquisition of drive and relay signals, Energy management system applications like AGC, VAR Control, State estimation, Security monitoring, Load management. digital relaying, Power plant instrumentation.

Smart Grids: Objectives and main features of smart grid; applications – new products, new consumer paradigm, communication requirements for smart grids, Monitoring, , Network protocol development and performance evaluation for smart grids, Concept of Micro Grid, Smart metering, Virtual Power Plant,

Course Learning Outcome: On the completion of the course, the student will be able

- To understand the SCADA organization and structure.
- To implement the concept of state estimation, multi-area state estimation.
- To understand the smart grid concepts and its application
- To familiarise with the concept of smart grid, micro grid, smart metering and virtual power plant

Recommended Books

1. *Torsten Cegrell " Power System Control Technology", Prentice–Hall of India Private Limited (1986).*
2. *Kusic C. L., "Computer Aided Power System Analysis", Prentice–Hall of India Private Limited (2007).*
3. *Wood A. J. and Wollenberg B. " Power generation operation and control", John Wiley and Sons (2007).*
4. *Cerni R.H and Foster L.E., "Instrumentation for Engineering Management", John Wiley and Sons (1962).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE339 POWER SYSTEM OPERATION UNDER DEREGULATION

L	T	P	Cr
3	1	0	3.5

Course Objectives: To understand the deregulation of electric utilities, restructuring models, ISO and trading arrangements, Open access transmission system with examples , To understand concept of wheeling of power

Deregulation: Introduction, Deregulation of electric utilities, Competitive whole sale electricity market: Transmission expansion in new environment, Transmission open access, pricing electricity in deregulated environment

Fundamentals of Deregulation: Privatization and deregulation, Motivations for Restructuring the Power industry; Restructuring models and Trading Arrangements: Components of restructured systems, Independent System Operator (ISO): Functions and responsibilities, Trading arrangements (Pool, bilateral & multilateral)

Open Access Transmission Systems: Different models of deregulation: U K Model, California model, Australian and New Zealand models, Deregulation in Asia including India, Bidding strategies, forward and Future market; Operation and control: Old vs New, Available Transfer Capability, Congestion management, Ancillary services.

Wheeling charges and pricing: Wheeling methodologies, pricing strategies

Course Learning Outcome: On the completion of the course, the student will be able

- To understand issues related to whole sale electricity market.
- To make comparison estimation of prevailing open access transmission models.
- To conceptualise the wheeling of power and price strategies
- To understand the electricity business

Recommended Books

1. *Yong-Hua song, Xi-Fan wang, "Operation of Market oriented Power systems", Springer(2003).*
2. *Electricity markets, report of planning commission India*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE343 RENEWABLE ENERGY SYSTEMS

L	T	P	Cr
3	1	2	3.5

Course Objectives: To understand the basics and need of alternate energy sources. their current status in India , and worldwide , To know the steps in conversion of solar and wind energy into electricity, to study wind and photovoltaic energy conversion in detail . in detail converters used and different storage devices

Introduction: Energy resources: renewable energy: solar, wind, hydropower, biomass, geothermal, ocean wave; benefit, costs, and policies of renewable energy; Environmental issues of energy services, renewable sources integration – overcoming intermittence; centralized vs. distributed generation.
Fundamentals of Wind Energy Conversion System Control : Speed and Power Relations, Power Extracted from the Wind, Horizontal- and Vertical-Axis Wind Turbines, Fixed-and Variable-Speed Turbine, Aerodynamic Power Control: Passive Stall, Active Stall, and Pitch Control, Tip Speed Ratio, Wind Generators.
Power Converters in Wind Energy Conversion Systems : Wind Energy System Configurations**,** Fixed-Speed Induction Generator WECS , Variable-Speed Wind Energy Systems with Squirrel Cage Doubly Fed Induction Generator Based WECS, Variable-Speed Wind Energy Systems with Synchronous, Permanent Magnet Generator (PMG). Control of DFIG & PMG
Solar Photovoltaic Power System: Solar PV cell panel, operation, design of solar thermal System, Stand-alone & Grid connected systems: Optimal economic coordinated operation of conventional and renewable sources, Operational issues and challenges
Energy storage systems and their applications; Fuel Cells, Superconducting magnetic systems, Pumped storage unit, Plug-in Hybrid Electric Vehicle (PHEV)

Course Learning Outcome: On the completion of the course, the student will be able

- To be familiar the current status of generation of energy(both renewable and nonrenewable in India and worldwide
- To understand different conversion ,solar and wind to electricity , Wind and Solar Technology in detail.
- To understand the basic of converter used in Wind and Solar
- To understand the designing of Solar panel , grid connection issues
- To be familiar with different ways to store electricity and their applications

Recommended Books

1. *Simon , Christopher A., Alternate Source of Energy, Rowman and Little Field Publishers Inc.(2007).*
2. *Patel, M. R., Wind and Solar Power Systems. Boca Raton, FL: CRC Press, (1999)*
3. *Venikov, V.A. and Putyain, E.V., Introduction to Energy Technology, Mir Publishers (1990).*
4. *Masters G. M., Renewable And Efficient Electric Power Systems, John Wiley & Sons, (2004).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	20
2.	EST	40
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40

PEE309 POWER QUALITY & CUSTOM POWER

L	T	P	Cr
3	1	0	3.5

Course Objectives: To understand the basics and need of power quality indices, non linear and unbalanced loads and their characteristics, measurement of electrical quantities and their analysis in frequency and time domain, remedial techniques for improvement in power quality

Introduction: Introduction – Characterisation of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – power quality problems: poor load power factor, Non-linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage – Power quality standards.

Non-Linear Loads: Single phase static and rotating AC/DC converters, Three phase static AC/DC converters, Battery chargers, Arc furnaces, Fluorescent lighting, Induction lamp, HID ballast, pulse modulated devices, Adjustable speed drives.

Measurement And Analysis Methods: Voltage, Current, Power and Energy measurements, power factor measurements and definitions, event recorders, Measurement Error – Analysis: Analysis in the periodic steady state, Time domain methods, Frequency domain methods: Laplace's, Fourier and Hartley transform – The Walsh Transform – Wavelet Transform.

Analysis And Conventional Mitigation Methods: 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 – Harmonic indices – Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI)- Analysis of voltage flicker, Reduced duration and customer impact of outages, Classical load balancing problem: Open loop balancing, Closed loop balancing, current balancing, Harmonic reduction, Voltage sag reduction.

Power Quality Improvement: 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. Difference in role of FACTS devices in transmission and distribution networks.

Course Learning Outcome: On the completion of the course, the student will be able

- To understand power quality standards.
- To identify linear and non linear loads.
- To know about various measurement techniques of voltage and current paparmeters.
- To analyse harmonics and their mitigation
- To acquire knowledge of custom power devices and their role in T&D system.

Recommended Books

1. *Ghosh, A. and Ledwich, G., Power Quality Enhancement using Custom Power Devices, Kluwer Academic Publishers (2002).*
2. *G.T.Heydt, "Electric Power Quality", 2nd Ed, , Stars in a Circle Publications, (1994).*
3. C. Sankaran, "Power Quality", CRC Press, 2002.
4. *Derek A. Paice, Power electronic converter harmonics, Prentice Hall Int., 2003*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	25

PEE308 RENEWABLE ENERGY SYSTEMS

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objectives: To impart knowledge about renewable energy resources, their control, Modes of operation and other energy storage systems

Introduction: Energy resources: renewable energy: solar, wind, hydropower, biomass, geothermal, ocean wave; benefit, costs, and policies of renewable energy; Environmental issues of energy services, renewable sources integration – overcoming intermittence; centralized vs. distributed generation.

Fundamentals of Wind Energy Conversion System Control : Speed and Power Relations, Power Extracted from the Wind, Horizontal- and Vertical-Axis Wind Turbines, Fixed-and Variable-Speed Turbine, Aerodynamic Power Control: Passive Stall, Active Stall, and Pitch Control, Tip Speed Ratio, Wind Generators.

Power Converters in Wind Energy Conversion Systems : Wind Energy System Configurations**,** Fixed-Speed Induction Generator WECS , Variable-Speed Wind Energy Systems with Squirrel Cage and Doubly Fed Induction Generator (DFIG)) Based WECS, Variable-Speed Wind Energy Systems with Synchronous, Permanent Magnet Generator (PMG). Control of DFIG & PMG

Solar Photovoltaic Power System: Solar PV cell panel, operation, design of solar thermal System, MPPT algorithm

Stand-alone & Grid connected systems: Optimal economic coordinated operation of conventional and renewable sources, Operational issues and challenges

Energy storage systems and their applications; Energy Storage systems, Fuel Cells, Superconducting magnetic systems, Pumped storage unit, Compressed Air storage unit, Plug-in Hybrid Electric Vehicle (PHEV)

Course Outcome: after the completion of the course the student may be able to

- To identify various renewable energy resources
- To realize their control strategies
- To analyse wind and solar dc system
- To conceptualize operation of renewable sources in standalone mode and grid connected mode

***Recommended* Books**

1. *Simon , Christopher A., Alternate Source of Energy, Rowman and Little Field Publishers Inc.(2007).*
2. *Patel, M. R., Wind and Solar Power Systems. Boca Raton, FL: CRC Press, (1999)*
3. *Venikov, V.A. and Putyain, E.V., Introduction to Energy Technology, Mir Publishers (1990).*
4. *Masters G. M., Renewable And Efficient Electric Power Systems, John Wiley & Sons, (2004).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	35
3.	Sessionals (May include Assignments/Projects/Tutorials/Quizes etc.)	40