THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Scheme & Syllabi
ME
(Power Systems)

w.e.f. 2019

(Revision of Scheme and Syllabi)

Through
DPPC, EIED dated March 05, 2018

Through
Board of Studies (BOS), EIED dated March 12, 2018

Electrical and Instrumentation Engineering Department

ME (Power Systems) *w.e.f. 2019*

First Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1	PEE106	Modelling and Analysis of Power System	3	1	2	4.5
2	PEE109	Power System Dynamics and Stability	3	1	0	3.5
3	PEE110	Protective Relaying	3	0	2	4.0
4	PEE111	High Voltage Technology	3	0	2	4.0
5	PEE209	Real Time Simulation of Energy Systems	3	0	2	4.0
6	PEE210	Advanced Power Converters	3	1	2	4.5
		Total	**18**	**3**	**10**	**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	PEE221	FACTS Controllers and Modelling	3	0	0	3.0
3	PEE205	Intelligent Algorithms in Power Systems	3	1	2	4.5
4	PEE216	Digital Control Systems	3	1	0	3.5
5		Elective-I	3	0	0	3.0
6		Elective–II	3	0	2	4.0
		Total	**18**	**3**	**6**	**22.5**

Contact hrs./week: 27
Credits Second sem: 22.5

Third Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEE391	Seminar	-	-	-	4.0
2.	PEE394	Project	-	-	-	4.0
3.	PEE492	Dissertation (Start)	-	-	-	-
		Total	**-**	**-**	**-**	**8.0**

Fourth Semester

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

List of Elective

Elective–I

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEE231	Extra High Voltage Transmission Systems	3	0	0	3.0
2.	PEE207	Power System Planning and Restructuring	3	0	0	3.0
3.	PEE232	Micro and Smart Grid	3	0	0	3.0
4.	PMA102	Research Methodology	2	0	2	3.0

5.	PEE233	Power System Transients and Mitigation	3	0	0	3.0
6.	PEE234	Power Quality and Custom power	3	0	0	3.0
7.	PEE235	Distribution Systems: Operation and Analysis	3	0	0	3.0
8.	PEE236	Load and Energy Management	3	0	0	3.0

Elective–II

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEE241	Digital Signal Processing	3	0	2	4.0
2.	PEE203	Electric Drives and Control	3	0	2	4.0
3.	PEE321	Digital Controllers and Applications	3	0	2	4.0
4.	PCL108	Statistical Methods and Algorithms	3	0	2	4.0
5.	PEE242	Renewable Energy Systems	3	0	2	4.0
6.	PCS206	Machine Learning	3	0	2	4.0

Summary

S. No.	Semester (Year)	Contact Hrs.	Credits
1.	I (First)	31	24.5
2.	II (First)	27	22.5
3.	I (Second)		8.0
4.	II (Second)		16.0
	Total Credits		71.0

PEE109: POWER SYSTEM DYNAMICS AND STABILITY

L	T	P	Cr
3	1	0	3.5

Course objectives: To impart knowledge on dynamic models of single and multi-synchronous machines based power system and to discuss the concept of small signal stability, voltage stability and sensitivity analysis

Elements of synchronous machine Modeling: Introduction to dynamics and stability studies in power system, Mathematical modeling of power systems components, Conventions and notations, three-damper-winding model, Transformation and scaling: Park's transformation, synchronous machine dynamic equations, concept of linear and non-linear magnetic circuits in synchronous machine modeling, single machine steady state model.

Control models of synchronous machines: Fundamentals of voltage and speed control, exciter model, voltage regulator models, turbine models, speed-governor models.

Single synchronous machine dynamic model: Single machine dynamic model, multi-time-scale model, Elimination of stator/ network transients; Two-axis model, One-axis model, classical model, one-axis dynamic model considering damping terms, machine model considering saturation.

Multimachine dynamic models: Concept of synchronously rotating reference frame, Network and R-L load constraints, Elimination of stator/network transients, two–axis model, one–axis model (flux-decay model), classical model, accounting the effects damping torques, saturation, frequency during transients. Introduction to development and simulation of multi-machine dynamic models, Stator Algebraic Equations, Network Equations, Simplification of Two–axis model, Reduced–order multi–machine models.

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 : Application of software such as EMTP, MATLAB etc. for modeling of single and multi-machine power system, 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 will be able to

- develop the dynamic models of single and multi-synchronous machines in power system.
- simulate single and multi-machine dynamic model of power system.
- analyze small signal stability of power system.
- apply energy function method for analysis of transient stability in power system.
- 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.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	25

PEE210: ADVANCED POWER CONVERTERS

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

Power Semiconductor Devices: Structure, characteristics, ratings of Thyristor, Power BJTs, Power MOSFETs, Static induction transistors (SITs), Insulated Gate Bipolar Transistors (IGBTs), MOS-controlled thyristors (MCTs), comparison of controllable switches, Drive andSnubber circuits.

DC-DC Switch Mode Converters: Switched Mode Power Conversion, Switch realization, Non-isolated DC-DC Converters: Buck, Boost, Buck-boost, Cuk and SEPIC converters – operations in CCM and DCM, non-idealities. Isolated DC-DC Converters: Flyback, Forward and Push-pull topologies.

DC-AC Inverters: Single phase half and full bridge voltage source inverters, pulse width modulated inverters, three phase inverters, voltage control of three phase inverter, space vector PWM, Hysteresis current control, selective harmonic elimination, Current source inverters.

Multilevel Inverter: Diode Clamped MLI, Capacitor clamped MLI, Flying Capacitor MLI, Cascaded H-Bridge topology: operation with equal and unequal DC voltages, Carrier modulation schemes of multilevel inverter, SVPWM of Multilevel inverter, selective harmonic elimination, Neutral Point Balancing schemes.

AC- AC Converters: Review of Single-phase AC regulator; Three-phase AC regulators, Single-phase and three-phase Cyclo-converters; Three phase matrix converters and their control.

Standards in Power Converters: Safety requirements (IEC62477-1:2012), Battery chargers (NEMA 5-7, 1997), Harmonic distortion standards (IEC/IEEE)

Applications: Interfacing converters with grid, UPS, Induction heating, Reactive power compensation, STATCOM, Renewable energy.

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
- design the Gate and base drive circuits
- develop skills to utilize the different PWM schemes
- validate the performance of different types of power converters
- 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.	Sessional (May include Assignments/Projects/Tutorials/Quizzes 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.

Short circuit studies: Sequence impedances and networks for power system components, Fault analysis of balanced and unbalanced faults in small and large system.

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.

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.

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 Contingency analysis 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.
- carry out power system analysis techniques and optimal power flow.
- handle issues related to unit commitment, economic thermal and hydro-thermal scheduling.
- analyse the behavior of system during short circuit and the important of contingency analysis.
- 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)*
7. *Wood, A.J. and Wollenberg, B.F., Power Generation, Operation and Control, John Wiley and Sons (2003)*

Evaluation Scheme:

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

PEE233: POWER SYSTEM TRANSIENTS AND MITIGATION

L	T	P	Cr
3	0	0	3.0

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
- identify the protection schemes of power system equipment from overvoltages like ground wires, surge absorbers and arrestors.
- design of insulation of power system components
- 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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE110: 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. Introduction to IEC protocols

Current and Voltage Transducers: Their features and characteristics under steady state and transient conditions.

Static Relays: 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, Directional relay, Differential relay, Distance relays, Switched distance relay, Poly-phase relay, Frequency relay.

Protection of Bus-bar, Transformer and Generator: High impedance and low impedance differential protection schemes, Protection schemes for busbar, transformer and generator.

Digital Protection of Feeder and Transmission Line: Protection criteria for distribution system, Feeder Protection, Auto-reclosers and Sectionalizers, Coordination of overcurrent, distance and directional relay, Distance protection scheme, Stepped time distance characteristics for distance relays, Effect of arc resistance & power surges on performance of Distance Relays, Wire Pilot protection schemes, Carrier current Protection schemes, Integrated substation protection and control.

Numerical protection: Numerical Relay,Data Acquisition System, Numerical Relaying Algorithms, Removal of DC offset, Numerical overcurrent, Distance and Differential Protection, Realization of Microprocessor based Overcurrent, Directional, Impedance, Reactance, MHO and Quadrilateral Relays, Applications of Digital protection schemes for transmission lines, transformers and Generators, ANN based Numerical Protection.

Standards in Protection: IEEE/IEC Protection Protocols

Laboratory Work: Experiments on differential relay, overcurrent relay, distance relay, Protection schemes for generator, transformer and transmission lines, Simulation of different types of faults in transmission line and transformer using SIMULINK.

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

- comprehend the characteristics of system transducers under different operating conditions.
- analyze the characteristics of different types of electromagnetic and static relays.
- design the protection schemes for feeders, transmission lines, generators and transformers.
- realize different microprocessor based numerical relays and protection schemes.

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. *B. Ram and D. N. Vishwakarma, Power System Protection and Switchgear, Tata McGraw Hill Education Pvt. Ltd. (2011).*
4. *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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	25

PEE205: INTELLIGENT 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 offuzzy 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.
- implement the concept of fuzzy logic concept and its implementation in controller applications
- 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.	Sessional (May include Assignments/Projects/Tutorials/Quizzes 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 Automatic load frequency control (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 automatic voltage regulator (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,
- formulate problems of the optimal system operation through optimal generation dispatch, unit commitment, hydro-thermal scheduling and pumped storage plant scheduling
- implement the optimal power system operation problems through various classical methods.
- 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.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	40

PEE207: POWER SYSTEM PLANNING AND RESTRUCTURING

L	T	P	Cr
3	0	0	3.0

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, Planning tools, Electricity Regulation, Forecasting: Load, Energy, Peak demand, Annual and monthly peak demand.

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

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, Green-house effect, Technological impacts. Transmission expansion in new environment, Transmission open access.

Restructuring: Operation of vertically integrated power systems, Models and examples of deregulated operation, Independent power producers (IPP) Optimal dispatch based on offers and bids, Power wheeling, Transmission pricing and congestion, Allocation of spinning reserve, Demand side bidding, Pricing schemes, Competitive electricity markets. Independent System Operator (ISO): Functions and responsibilities, Trading arrangements (Pool, bilateral & multilateral)

Open Access Transmission Systems: Case Studies: 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

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 significance of power system restructuring and integrated generation.
- formulate the power system generation expansion as an optimization problem with cost, emission and reliability as major constraints
- qualify the technological impacts of transmission & distribution planning under uncertainty factors
- 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.*
5. *Yong-Hua song, Xi-Fan wang, "Operation of Market oriented Power systems", Springer(2003).*
6. *Electricity markets, report of planning commission India*

Evaluation Scheme:

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

PEE221: FACTS CONTROLLERS AND MODELLING

L	T	P	Cr
3	0	0	3.0

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), 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.
- analyse the operational aspects and their effectiveness in transient stability enhancement,
- assess the issues of damping to power system oscillations, real and reactive power control capability in power system
- 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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE209: REAL TIME SIMULATION OF ENERGY SYSTEMS

L	T	P	Cr.
3	0	2	4.0

Course objective: To introduce the students about important contemporary issues due to the integration of DG: technical challenges, benefits, and perspectives in real time environment. To make familiar with hardware components including measurement and control in hardware in loop system.

Introduction: Hardware-in-loop simulation systems, distributed control architecture, reliability enhancement by redundancy, Real time operating systems: Features, primary components, Structured design of real time systems.

Developing a mathematical model for Power system and control, Mathematical model of the real environment, Design of hardware device meant to be used in HIL, Power Amplifier

Testing and parameter adjustment for real time implementation of real-time simulator, Design of desired control schemes for AC and DC electrical machine drives and other applications: Micro-grid and renewable and its testing in HIL.

Real time control strategy based on FPGA, dSpace, Understanding four-quadrant amplifier for HIL system.

Laboratory work: Off-line simulations for the various experiments related to hardware in-the-loop simulation system to predict ahead of conducting the lab experiment the operating characteristics and compare results; Microgrid operation and control using HIL; Implement hardware such as PV and Wind system on the simulated grid to test hardware device in the real environment.

Course learning Outcomes (CLO):

After the completion of the course the students will be able to:

- Demonstrate about Hardware-in-loop simulation systems.
- Explain about mathematical model for power system and control in real environment.
- Design control schemes for AC and DC electrical machine drives.
- Demonstrate the concepts of real time control strategy based on FPGA, dSpace, Opal-RT, RTDS simulators.

Recommended Books:

1. *N. Hatziargyriou "Microgrids: Architectures and Control", Wiley-IEEE Press, January (2014).*
2. *HIL System catalogues; Opal-RT, RTDS and Typhoon.*

Evaluation Scheme:

S N	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	50
3.	Sessional (Assignments/Projects/Tutorials/Quizzes/Lab Evaluations)	20

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 andsignal 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.

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

- learn about the discrete digital control system
- perform the stability analysis using various techniques,
- 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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE235: DISTRIBUTION SYSTEMS: OPERATION AND ANALYSIS

L	T	P	Cr
3	0	0	3.0

Course Objectives: To know about the distribution system and it's planning and 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
- familiarization with distribution system configurations, loads, power flow,
- analyse the effect of reconfigurations
- 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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE231: EXTRA HIGH VOLTAGE TRANSMISSION SYSTEMS

L	T	P	Cr
3	0	0	3.0

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.
- analyse system dynamic performance and reactive power requirements.
- know about corona and radio & TV interference.
- design filters for reduction of harmonics.
- 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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE241: DIGITAL SIGNAL PROCESSING

L	T	P	Cr
3	0	2	4.0

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, ADC and DAC 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, Finite and Infinite Impulse Response Filters (IIR,FIR)

Multi-rate 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
- analyse continuous and discrete signals in frequency domain.
- implement the concepts for measurement of frequency, harmonic level etc.
- design digital filters for reduction of noise signals
- 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	45
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	25

PEE203: ELECTRIC DRIVES AND CONTROL

L	T	P	Cr
3	0	2	4.0

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.
- apply their knowledge to prepare control schemes as per different types of motors used in industries.
- 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	45
3	Sessional	30

PEE111: HIGH VOLTAGE TECHNOLOGY

L	T	P	Cr
3	0	2	4

Course Objectives: Familiarization with different causes of high overvoltage occurrence and the protective devices used to mitigate the same is considered as initial objective of this course. Learning the principle of insulation coordination as per recommended standards is another prime objective, while imparting the knowledge on GIS, test techniques and diagnostic methods for high voltage electrical apparatus are the basic needs of this course.

Introduction: Power Systems development and high voltage engineering; breakdown phenomena in solid, liquid and gaseous insulating materials, Applications of insulating materials in different parts of power systems, Applications of High Voltage Technology, Transmission line tower structures for HV, EHV and UHV systems

Overvoltages on Power Systems: Origin and Types of overvoltages- external and internal, Lightning as cause of external overvoltage: Lightning formation, Lightning overvoltages (strike and back flashover), Lightning overvoltages protection devices, Protection system of high buildings. Switching Overvoltages and temporary over voltages as cause of internal overvoltages, Control of switching overvoltages, EMTP and its applications.

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

Surge Arresters and Insulation Coordination: Surge arresters (MOA) and its performances, Properties of ZnO material for application as surge arrester, Voltage–Time Characteristics and coordination, Surge arresters selection and location in power systems, Principles of insulation coordination, Recommendations and definitions for insulation coordination as per IEC 60071, Statistical and conventional insulation coordination.

High Voltage AC and DC Cables: Configuration and design features of high voltage cables, voltage ratings- MV, HV and EHV, Polymer insulated power cables, Testing of high voltage cables: prequalification and development tests, type approval testing, sample testing, routine testing, future trends in testing, Diagnostics of high voltage cables.

Gas Insulated Substation: Fundamental aspects of air and SF_6 breakdown, U–curve and gap factor, Spark-over characteristics, SF_6 gas insulation performance; Gas Insulated Substation (GIS) and its importance, Configuration and design features of GIS, Prospects of GIS.

High Voltage Test of Electrical Apparatus: Non-destructive insulation testing, Destructive insulation tests: AC, DC and Impulse testing of apparatus, Test voltage recommendations and definitions as per IEC 60060 Parts 1 and 2 High Voltage Test Technique,Generation Techniques of High voltage DC, AC and Impulse, High voltage measurement technology; Partial discharge measuring techniques, Layout and Safety features in high voltage laboratory.

New Trends In High Voltage Technology: New materials for solid insulations: polymer nanocomposites, thermoplastic elastomers and their nanocomposites, New materials for liquid insulations: nano-fluids, New testing techniques and standards in high voltage apparatuses.

Laboratory Work: Non- destructive testing: Measurement of C-tanδ for solid and liquid insulations; Thermal tests on insulations, Corona discharge realization, Construction of HVAC and HVDC waves, Impulse voltage generation and measurement, partial discharge measurement, flash over voltage test of disc insulator, determination of break down voltage of different types of insulating paper/ tape samples, modelling and simulation of high voltage test techniques.

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

- understand the causes of high overvoltage in power system and able to select protective devices to be used.
- select surge arresters and develop strategies for insulation coordination as per recommended standards.
- perform different tests and diagnose different high voltage electrical apparatuses.
- understand the operation and performance of gas insulated sub-station (GIS).
- realize the latest trend in insulating materials and test techniques for high voltage applications.

Recommended Books

1. *Haddad A. and Warne D.F., Advances in High Voltage Engineering, IEE Power and Energy Series (IET),(2004).*
2. *Ryan H.M., High-voltage Engineering and Testing, IET, U.K. 3rd edition, (2013).*
3. *Khalifa M., High-Voltage Engineering, Theory and Practice, Marcel Dekker Inc (2000).*
4. Kind, D. and Feser, K, High Voltage Test Techniques, Reed Educational and Professional Publishing Limited (2001).
5. IEC 60060-2:2010, High-voltage test techniques - Part 1 &2: Measuring systems, https://webstore.iec.ch/publication/301#additionalinfo
6. IEC 60071-:2006, Insulation co-ordination - Part 1 and 2 https://webstore.iec.ch/publication/578
7. *Dissado, Len A., and John C. Fothergill, Electrical degradation and breakdown in polymers*. Vol. 9. IET, (1992).

Evaluation Scheme:

S. No.	**Evaluation Elements**	**Weightage (%)**
1.	MST	25
2.	EST	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	25

PEE321: DIGITAL CONTROLLERS AND APPLICATIONS

L	T	P	Cr
3	0	2	4.0

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..
- identify the architecture of processor concepts for I/O.
- 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	30
2.	EST	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE236: LOAD AND ENERGY MANAGEMENT

L	T	P	Cr
3	0	0	3.0

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

- familiar with different load forecasting method used in power system,
- understand different phase of load management and impacts of load management
- understand the concept of energy demand and method to satisfy meet the energy demand
- understand the measurement of energy conservation and its case studies
- familiar with ways of saving electricity in different utilities. Different phase of energy audit.
- 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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE242: RENEWABLE ENERGY SYSTEMS

L	T	P	Cr
3	0	2	4.0

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.

Solar Photovoltaic Power System: Photovoltaic Cell, electrical equivalent circuit, Solar PV cell panel, I-V characteristics, MPPT operation, solar thermal System, Stand-alone & Grid connected systems: Optimal economic coordinated operation of conventional and renewable sources, Operational issues and challenges. Economics of solar based energy systems.

Fundamentals of Wind Energy: Speed and Power Relations, Power Extracted from the Wind, Maximum rotor efficiency, 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 Energy Conversion Systems: Wind energy system configurations**,** Wind turbine generators, Fixed-Speed Induction Generator, variable-speed squirrel cage and Doubly Fed Induction Generator (DFIG) , Variable-speed wind energy systems with synchronous, Permanent Magnet Generator (PMG). Control of DFIG & PMG. Wind power economics.

Bio-gas energy conversion Systems, Integrated Energy Systems

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).

Standards: Standards of Power converters for solar PV system, Standards for energy storage systems.

Laboratory: I-V and P-V characteristics of PV Module, I-V and P-V characteristics of series and parallel combination of PV Module, Effect of shading of module output power, Study charging and discharging characteristics of battery, Observation of current waveform for linear and nonlinear load and calculations, Impact of transmission line inductance on voltage quality at PCC, Power factor correction using capacitor banks and its impact on power quality at PCC, Change in THD with change in transmission line inductance, Study of PV-emulator, Hybrid PV-wind simulator.

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

- identify various renewable energy resources available for power generation
- realize working fundaments and economics of different renewable energy systems
- analyze wind and solar based energy systems
- conceptualize operation of renewable sources in standalone mode and grid connected mode
- be familiarize with different energy storage systems.

***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).*
5. *Freris, L.L., Wind Energy Conversion Systems, Prentice Hall, London, (1990).*

Evaluation Scheme:

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

PEE234: POWER QUALITY AND CUSTOM POWER

L	T	P	Cr
3	0	0	3.0

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 – Characterization 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.
- identify linear and non linear loads.
- know about various measurement techniques of voltage and current parameters.
- analyse harmonics and their mitigation
- 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	50
3.	Sessional (May include Assignments/Projects/Tutorials/Quizzes etc.)	20

PEE232: MICRO AND SMART GRID

L	T	P	Cr
3	**0**	**0**	**3.0**

Introduction To Smart Grid: Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, Concept of Resilient & Self Healing Grid, Present development & International policies in Smart Grid, Diverse perspectives from experts and global Smart Grid initiatives.

Smart Grid Technologies : Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation ,Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control, Distribution systems: DMS, Volt/VAr control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV).

Smart Meters And Advanced Metering Infrastructure: Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit(PMU), Intelligent Electronic Devices(IED) & their application for monitoring & protection.

Power Quality Management In Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

High Performance Computing For Smart Grid Applications: Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Basics of Web Service and CLOUD Computing to make Smart Grids smarter, Cyber Security for Smart Grid.

Related Topics: Concept of Micro Grid, Virtual Power Plant

Course Outcome: After the completion of the course the student will be able to

- study about Smart Grid technologies, different smart meters and advanced metering infrastructure.
- familiarize the power quality management issues in Smart Grid.
- familiarize the high performance computing for Smart Grid applications

Recommended Books:

1. *Vehbi C. Güngör, DilanSahin, TaskinKocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, Smart Grid Technologies: Communication Technologies and Standards IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.*
2. *Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang "Smart Grid – The New and Improved Power Grid: A Survey" , IEEE Transaction on Smart Grids,*
3. *Stuart Borlase "Smart Grid :Infrastructure, Technology and Solutions", CRC Press 2012.*
4. *Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley.*

Evaluation Scheme:

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

PEE394: PROJECT

L	T	P	Cr
0	0	0	4.0

Course Objectives: The course is designed to help the students to develop problem solving skills, which may include a thorough survey of a particular domain, finding a problem pertaining to research /industry and presenting a methodology to resolve the problem with adequate experimental results to strengthen the contribution. Students are also supposed to learn about communicating the impact of their work by different tools which includes video, poster and presentation.

Course Learning Objectives:

After the completion of the course, the students will be able to:

- Identify, formulate and analyze of domain specific research or industrial problem.
- Propose a methodology to solve identified research or industrial problem.
- Ability to analyze the impact/contribution of the work to the industry or research.
- Ability to communicate and present the work to the relevant audience.

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	Panel of Examiner's (within department)	100

PEE391: SEMINAR

L	T	P	Cr
0	0	0	4.0

Course Objectives: To impart technical and research reading and writing skills to the students.

Course Description: The students will select a topic relevant to industry/research area. The seminar topic will challenge students to apply critical thinking skills to find the research gap. The faculty supervisor of the seminar will continuously assess the progress of the works of the assigned student. Each student will have to submit a detailed report of the seminar along with a power point presentation.

Course Learning Outcomes:

After the completion of the course, the students will be able to:

- Identify gaps for research work design goals and analyze possible approaches to meet given specifications with realistic engineering constraints.
- Understand modern engineering methods and tools.
- Prepare technical report.
- Deliver presentation on the research topic.

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	Panel of Examiner's (within department)	50
2.	Assessment by Supervisor	50

PEE492: DISSERTATION

L	T	P	Cr
0	**0**	**0**	**16.0**

Course Objectives: To impart the knowledge to understand the research methodology, carry out research in thrust areas and write a comprehensive report.

Course Learning Outcomes (CLO):

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

- Design and implementation of identified research problem or industrial projects.
- Develop acumen for higher education and research.
- Write technical reports and publish the research work in referred journals, national and international conferences of repute.
- Foresee how their current and future work will influence/impact the economy, society and the environment.

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	Panel of Examiner's (As approved by DoAA)	50
2.	Assessment by Supervisor	50