ODISHA UNIVERSITY OF TECHNOLOGY AND RESEARCH

Techno Campus, Mahalaxmi Vihar, Ghatikia, Bhubaneswar-751029.

Syllabus (Effective from 2023-24)

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

Abbreviation used:

AC	Audit course	LC	Lab Course	PA	Practical Assessment
PC	Professional Core	PR	Project/ Practical/ Internship	L	Lecture
PE	Professional Elective	SE	Seminar/ Expert Lecture/ Etc.	T	Tutorial
OE	Open Elective	IA*	Internal Assessment	P	Practical
MC	Mandatory/ Common Course	EA	End-Semester Assessment		

Subject Code Format:

A1 A2	B3	C4	C5 C6
School/ Dept. (Offering) **BH:** Basic Sciences and Humanities **CS:** Computer Sciences **EE:** Electrical Sciences **EI:** Electronic Sciences **IP:** Infrastructure and Planning **MS:** Mechanical Sciences **BT:** Biotechnology **TE:** Textile Engineering	**Level** **1:** UG/ Int. Msc. (1st Year) **2:** UG/ Int. Msc. (2nd Year) **3:** UG/ Int. Msc. (3rd Year) **4:** UG/ Int. Msc. (4th Year) **5:** UG/ Int. Msc. (5th Year) **6:** PG (1st Year) **7:** PG (2nd Year) **8:** Ph.D.	**0:** AC **1:** PC **2:** PE **3:** OE **4:** MC **5:** LC **6:** PR **7:** SE **8:** **9:**	**Serial Number (01 to 99)** 01/ 03/…/ 19: Odd Sem. (ESM) 21/ 23/…/ 39: Odd Sem. (PED) 41/ 43/…/ 59: Odd Sem. (PSE) 61/ 63/…/ 79: Odd Sem. (Prog-4) 81/ 83/…/ 99: Odd Sem. (Prog-5) 02/ 04/…/ 20: Even Sem. (ESM) 22/ 24/…/ 40: Even Sem. (PED) 42/ 44/…/ 60: Even Sem. (PSE) 62/ 64/…/ 80: Even Sem. (Prog-4) 82/ 84/…/ 98: Even Sem. (Prog-5)

1st Semester

Sl. No.	Subject Type	Subject Code	Subject Name	Teaching Hours			Credit	Maximum Marks			
				L	**T**	**P**		**IA**	**EA**	**PA**	**Total**
1	PC 1	EE6141	Power System Analysis	3	0	0	3	40	60	-	100
2	PC 2	EE6143	Power System Dynamics and Control	3	0	0	3	40	60	-	100
3	PE 1 (Any One)	EE6241	Storage Technology	3	0	0	3	40	60	-	100
		EE6243	Advanced Control System								
		EE6245	Power System Transients								
4	MC 1	BH6401	Mathematical Methods in Engineering	3	0	0	3	40	60	-	100
5	MC 2	MS6403	Research Methodology and IPR	2	0	0	2	40	60	-	100
6	LC 1	EE6541	Power System Simulation Lab	0	0	4	2	-	-	100	100
7	LC 2	EE6543	Power Electronics Lab	0	0	4	2	-	-	100	100
8	AC 1	Any One from the List of AC 1 (Appendix-I)		2	0	0	0	40	60	-	100
			Total	**16**	**0**	**10**	**18**	**240**	**360**	**200**	**800**

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2nd Semester

Sl. No.	Subject Type	Subject Code	Subject Name	Teaching Hours L	T	P	Credit	Maximum Marks IA	EA	PA	Total
1	PC 3	EE6142	Digital Protection	3	0	0	3	40	60	-	100
2	PC 4	EE6144	Distribution System Engineering	3	0	0	3	40	60	-	100
3	PE 2 (Any One)	EE6242	Switched Mode Power Conversion	3	0	0	3	40	60	-	100
		EE6244	AI and Machine Learning								
		EE6246	Demand Side Management and Demand Response								
4	PE 3 (Any One)	EE6248	Advanced DSP	3	0	0	3	40	60	-	100
		EE6250	Smart Grid Technology								
		EE6252	Power System Planning								
		EE6254	High Voltage Engineering								
5	OE 1	Any One from the List of OE 1 (Appendix-I)		3	0	0	3	40	60	-	100
6	PR 1	EE6642	Project (Specialization Related)	0	0	4	2	-	-	100	100
7	LC 3	EE6542	Renewable Energy Lab	0	0	4	2	-	-	100	100
8	AC 2	Any One from the List of AC 2 (Appendix-I)		2	0	0	0	40	60	-	100
			Total	**17**	**0**	**8**	**19**	**240**	**360**	**200**	**800**

3rd Semester

Sl. No.	Subject Type	Subject Code	Subject Name	Teaching Hours L	T	P	Credit	Maximum Marks IA	EA	PA	Total
1	PE 4* (Any One)	EE7241	Grid Integration of Renewable Sources	3	0	0	3	40	60	-	100
		EE7243	Electric Power System Market								
		EE7245	FACTs and Customer Power Devices								
		EE7247	Power Quality								
		EE7249	EHVAC Transmission								
2	PR 2	EE7641	Dissertation (Phase-I)	0	0	24	12	-	-	100	100
			Total	**3**	**0**	**24**	**15**	**40**	**60**	**100**	**200**

* Virtual/Online Course either offered by OUTR or available in MOOCs platform (No physical class)

4th Semester

Sl. No.	Subject Type	Subject Code	Subject Name	Teaching Hours L	T	P	Credit	Maximum Marks IA	EA	PA	Total
1	PR 3	EE7642	Dissertation (Phase-II)	0	0	32	16	-	-	100	100
			Total	**0**	**0**	**32**	**16**	**-**	**-**	**100**	**100**

Credits and Maximum Marks

Sl. No.	Semester	Credits	Maximum Marks
1	1st	18	800
2	2nd	19	800
3	3rd	15	200
4	4th	16	100
	Total	68	1900

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1st Semester

PC 1	EE6141	Power System Analysis	3	0	0	3

Module I:

Load Flow: Overview of Gauss-Siedel, Newton-Raphson, Fast Decoupled load flow methods, convergence properties, sparsity techniques, handling Q-max violations in constant matrix, inclusion in frequency effects, AVR in load flow, handling of discrete variable in load flow.

Optimal Power Flow: Optimal power flow (OPF), Formulation of Objective function, Equality and Inequality constraints, Solution of OPF by Gradient method, Security constrained OPF, Continuation power flow, Predictor and Corrector Method for continuation power flow.

Module II:

Optimal System Operation: Generation allocation problem formulation, Transmission Loss Formula, Loss Coefficients, Hydrothermal Coordination.

Unit Commitment: Introduction to Unit Commitment, constraints in Unit Commitment, Unit Commitment solution methods.

Module III:

Security Analysis: Security state diagram, contingency analysis, generator shift distribution factors, line outage distribution factor, multiple line outages, overload index ranking.

State Estimation: Sources of errors in measurement, Virtual and Pseudo, Measurement, Observability, Tracking state estimation, WLS method, bad data correction.

Suggested Books:

1. J.J. Grainger &W.D. Stevenson, "Power system analysis", McGraw Hill ,2003
2. A. R. Bergen & Vijay Vittal, "Power System Analysis", Pearson, 2000
3. L.P. Singh, "Advanced Power System Analysis and Dynamics", New Age International, 2006
4. G.L. Kusic, "Computer aided power system analysis", Prentice Hall India, 1986
5. A.J. Wood, "Power generation, operation and control", John Wiley, 1994
6. P.M. Anderson, "Faulted power system analysis", IEEE Press, 1995

COURSE OUTCOMES: At the end of the course, students will be able to:

CO1: gain knowledge on formation of suitable mathematical model of a given power system network load flow analysis and optimal power flow.

CO2: gain knowledge on formation of suitable mathematical model for obtaining optimal performance during planning and operational conditions

CO3: gain knowledge on system contingencies, behavior of system to ensure security for the system operation and state estimation.

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PC 2	EE6143	Power System Dynamics and Control	3	0	0	3

Module I:

Power System Stability Problems: Basic concepts and definitions, rotor angle stability, synchronous machine characteristics, power versus angle relationship, modeling of synchronous machines and various loads (composite load model), modeling of excitation systems, turbine and governor systems

Generation Control Loops: Automatic Voltage Regulator (AVR) loop, Performance and response of AVR, Automatic Generation Control (AGC) of single and multi-area systems, Static and dynamic response of AGC loops.

Small Signal Stability: State space concepts, basic linearization techniques, participation factors, eigen properties of state matrix, small signal stability of a single machine infinite bus system, hoff-bifurcation, electromechanical oscillatory modes

Module II:

Large Perturbation Stability: Transient stability: time domain simulation and direct stability analysis techniques (extended equal area criterion), energy function methods: physical and mathematical aspects of the problem, Lyapunov's method, modeling issues, energy function formulation, potential energy boundary surface (PEBS), energy function formulation of a single machine infinite bus system, equal area criterion and energy function, Transient stability analysis of multi machine systems.

Low Frequency Oscillations: Power system model for low frequency oscillation study, Eigen value analysis, Improvement of system damping characteristics, Power system stabilizer (PSS) model, Turbine-generator torsional characteristics, shaft system model, torsional natural frequencies and mode shapes, torsional interaction with power system controls; Sub Synchronous Resonance (SSR) and remedial measures.

Module III:

Voltage Stability Analysis: Real and reactive power flow in long transmission lines, Effect of On Load Tap Changing (OLTC) transformers and load characteristics on voltage stability, Voltage stability assessment by P-V curves, Voltage stability limit, Static and dynamic modelling of power systems. Voltage Collapse Proximity Indicators (VCPI), Voltage stability enhancement techniques.

Suggested Books:

1. P. Kundur, "Power system stability and control", McGraw Hill, NY, 1994
2. P.Sauer and M.Pai, "Power System Dynamics an Stability", Prentice Hall, 1998.
3. A.J. Wood,B.F.Wollenberg "Power generation, operation and control", John Wiley, 1994
4. K.R.Padiyar, "Power System Dynamics, stability and control", Interline Publishing, Bangalore, India, 1999
5. M.A.Pai, D.P.Sengupta, K.R.Padiyar, "Small signal analysis of power systems", Narosa Series in Power and Energy Systems, 2004
6. C.VanCustem, T.Vournas, "Voltage stability of electric power systems", Riever Academic Press (UK), 1999
7. I.J.Nagrath, D.P.Kothari, "Power system engineering", Tata McGraw Hill Publishing Co, NewDelhi, India, 1994

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: gain knowledge on formation of suitable mathematical model of a given power system stability and Automatic Generation Control of single and multi-area systems.

CO2: gain knowledge on large signal and small signal stability aspects.

CO3: gain knowledge on voltage stability issues and methods for finding various stability indicators.

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
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PE 1	EE6241	Storage Technology	3	0	0	3

Module I - Introduction to energy storage technology and energy storage processes
The need for energy storage - Types and general concepts Energy storage processes:

- Electrical energy storage – Super capacitors: Fundamentals and types of super capacitors
- Magnetic Energy Storage – superconducting systems,
- Thermal Energy Storage – phase change materials,
- Mechanical - Pumped hydro, Flywheels and Compressed air energy storage,
- Chemical - Hydrogen Storage, Production and storage alternatives, Other approaches to hydrogen storage.

Module II- Electrochemical energy storage
Thermodynamics, Kinetics and electrochemistry of battery Systems Primary, secondary and Flow batteries.

Module III– System design & Applications

- Energy storage for renewable energy sources - Battery sizing and stand-alone Applications
- Large scale applications/ Stationary (Grid applications) – Power and energy applications
- Small scale applications - Portable storage systems/medical devices
- Mobile storage applications
- Electric vehicles - Introduction and types of EV's
- Batteries and fuel cells – future technologies
- Hybrid systems for energy storage

Books and References:

1. Energy Storage - Technologies and Applications, Ed: Ahmed Faheem Zobaa, ISBN 978-953-51-0951-8, 328 pages, Publisher: InTech, 2013.
2. J. Jensen and B. Sorenson. Fundamentals of Energy Storage. Wiley-Interscience, New York (1984)
3. Handbook of battery materials, Ed: C. Daniel, J. O. Besenhard, 2nd Edition, Wiley- VCH Verlag GmbH & Co. KgaA, 2011.
4. Electric & Hybrid Vehicles, G. Pistoia, Elsevier B.V, 2010.

COURSE OUTCOMES:
CO1: Understand various storage technologies.
CO2: Able to analyze the reliability, technical efficiency and economic efficiency of an integrated system.
CO3: Exposure to modern innovative technologies applied for energy storage in fuel cell, hydrogen storage, electromagnetic storage etc.
CO4: Design of battery in electric vehicles and hybrid systems

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PE 1	EE6243	Advanced Control System	3	0	0	3

Module I
Discrete-Time Systems
State Space Representations of Discrete Time Systems, Solution of Discrete Time State Equations, Discretization of Continuous Time State Equations, Digital PID Controller Controllability, Observability, Pole Placement by State feedback, Deadbeat response

Module II
Optimal Control (Continuous-Time and Discrete-Time Systems)
Performance Indices, Quadratic Optimal Regulator / Control Problems, Formulation of Algebraic Riccati Equation (ARE) for continuous and discrete time systems. Solution of Quadratic Optimal Control Problem using Lagrange Multiplies for continuous and discrete-time Systems, Evaluation of the minimum performance Index, Optimal Observer, The Linear Quadratic Gaussian (LQG) Problem, Pole Placement by State feedback using Optimal feedback Gain for Quadratic Regulator and LQG problem, Introduction to $H\infty$ Control.

Module III
Nonlinear and Adaptive Control
Stability: Basic concepts, Stability definitions and theorems, Lyapunov functions for LTI systems, Fractional Differentiation and its application
Model Reference Adaptive Control (using MIT Rule and Lyapunov Theory), Recursive Least Square Estimation, stochastic Self-Tuning Control (Minimum Variance and Pole-placement Control), Sliding Mode Control, Sliding mode control algorithms

Text Books

1. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 3rd Edition, 2009
2. J. J. E. Slotine and W. Li, Applied Nonlinear Control, Prentice Hall, 1991.
3. D. S. Naidu, Optimal Control Systems, CRC Press, 2002.
4. K.J. Astrom and B. Wittenmark, Adaptive Control, Pearson, 2006.
5. R. T. Stefani, B. Shahian, C.J. Savant, G.H. Hostetter, Design of Feedback Control Systems, OUP, 2002.

Reference Books

1. K. Ogata, Modern Control Engineering, Prentice-Hall of India, 5th Edition, 2010
2. K. Ogata, Discrete-Time Control System, 2nd edition (2001), Pearson Education Publication
3. H.K. Khallil, Non Linear Systems, 3rd edition (2002), Pearson Education
4. B. Friedland, *Control System Design - An Introduction to State-Space Methods*, McGraw-Hill, 2007
5. S.H. Zak, Systems and Control, Oxford Univ. Press, 2003

COURSE OUTCOMES.
On successful completion, students will have the ability to

CO 1: Analyse the stability of discrete system and nonlinear system
CO 2: Design compensators using classical techniques and Optimal Control Law
CO 3: Analyse both linear and nonlinear system using state space methods
CO 4: Understand the concept and implementation of Adaptive Control

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 1	EE6245	Power System Transients	3	0	0	3

Module I:
Fundamental circuit analysis of electrical transients, Laplace Transform method of solving simple Switching transients, Damping circuits -Abnormal switching transients, Three-phase circuits and transients, Computation of power system transients.

Module II:
Lightning, switching and temporary over voltages, Lightning, Physical phenomena of lightning, Interaction between lightning and power system, Influence of tower footing resistance and Earth Resistance Switching: Short line or kilometric fault, energizing transients - closing and re-closing of lines, line dropping, load rejection – over voltages induced by faults

Module III:
Travelling waves on transmission line, Circuits with distributed Parameters Wave Equation, Reflection, Refraction, Behaviour of Travelling waves at the line terminations, Lattice Diagrams – Attenuation and Distortion, Multi-conductor system and Velocity wave
Insulation co-ordination: Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated Substation (GIS) Co-ordination between insulation and protection level, Statistical approach
Protective devices, Protection of system against over voltages, lightning arresters, substation earthing

Suggested Books:

1. Allan Greenwood, “Electrical Transients in Power System”, Wiley & Sons Inc. New York, 1991
2. Lou Van der Sluis, “Transients in power Systems”, John Wiley & Sons Ltd, 2001

COURSE OUTCOMES:
At the end of the course, students will be able to:
CO1: Analyze various transients that could occur in power system and their mathematical formulation
CO2: design various protective devices in power system for protecting equipment and personnel
CO3: know about coordinating the insulation of various equipment in power system
CO4: Model the power system for transient analysis

School/ Department: School of Electrical Sciences
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MC 1	BH6401	Mathematical Methods in Engineering	3	0	0	3

Refer Appendix-I for detailed Syllabus.

MC 2	MS6403	Research Methodology and IPR	2	0	0	2

Refer Appendix-I for detailed Syllabus.

School/ Department: School of Electrical Sciences
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LC 1	EE6541	Power System Simulation Lab	0	0	4	2

Sl. No	Experiments	Hours
1	Simulation of Fault Studies with and without fault and neutral impedance(LG/LLG/LLL).	3×2
2	Simulation of Load Flow Studies (GS/NRLF/FDLF/Participation factor based load flow)	3×2
3	Simulation of State Estimation Studies.	3×1
4	Simulation of Continuation power flow	3×1
5	Simulation for overload security Analysis	3×1
6	Simulation for voltage security Analysis	3×1
7	Simulation of power system market clearing/ economic dispatch/ OPF	3×2

(All these would be exercised based on MATLAB programs with some IEEE system data. A student would be asked to do exercises by changing the input data of the given system and observing what is the output. The student will also have to analyze as to why this output is being observed)

COURSE OUTCOMES:
Students will be able to:
CO1: Analyze and calculate the different fault currents in different types of fault and comment on the difference in different network conditions.
CO2: Evaluate the voltage phasors in different load flow solution and comparing the speediness of operation and accuracy as compared to other methods.
CO3: Rank various contingencies according to their severity by the use of security analysis.
CO4: Estimate the voltage phasors according to the given network measurements.
CO5: Estimate the pricing of electric commodities according to market situations

School/ Department: School of Electrical Sciences
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LC 2	EE6543	Power Electronics Lab	0	0	4	2

Sl. No	Experiments	Hours
1	To Study single-phase (i) fully controlled (ii) Half controlled bridge rectifiers with resistive and inductive loads	
2	To Study three-phase (i) fully controlled (ii) Half controlled bridge rectifiers with resistive and inductive loads.	
3	To study operation of IGBT/MOSFET based Buck chopper	
4	To study operation Dual Converter with resistive and inductive loads.	
5	To Study single-phase AC voltage regulator with resistive and inductive loads	
6	To Study Three-phase AC voltage regulator with resistive and inductive loads	
7	To Study various pwm based single-phase bridge inverter	
8	To Study pwm based three-phase bridge inverter	
9	Calculation of input power factor and displacement factor for single phase rectifier circuit	
	Development of firing angle table for +ve, -veand zero sequence voltage for 3 ph inverter circuits	
10	Performance calculation of various rectifier circuit	

COURSE OUTCOMES:

Students will be able to

CO1: Understand and Analyze the performance parameters of converters.

CO2: Analyze Spectral content for Various PWM schemes.

CO3: Design the firing circuits employed for Power Electronic Converters.

AC 1	Any One from the List of AC 1 (Appendix-I)	2	0	0	0

Refer Appendix-I for detailed Syllabus.

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2nd Semester

PC 3	EE6142	Digital Protection	3	0	0	3

Module I:
Power system protection and its attributes, principle of operation of electromechanical relays, over current, differential, distance relaying concepts for power apparatus, reach setting of the relay, Distance relaying and R-X trajectories, Impedance, Reactance, MHO relay characteristic, balanced beam implementation of impedance relay, impact of infeed, arc resistance, power swing, line compensation on distance relay operation, out of step relay, loadability limit, loadability limit, differential and biased differential protection for transformer, Inrush phenomena and 2nd harmonic restraint protection.

Module II:
Evolution of digital relays from electromechanical relays, Performance and operational characteristics of digital protection, Mathematical background to protection algorithms. Basic elements of digital protection, Signal conditioning: transducers, surge protection, analog filtering, analog multiplexers, Conversion subsystem: the sampling theorem, signal aliasing, Error, sample and hold circuits, multiplexers, analog to digital conversion.

Module III:
Digital filtering concepts, the digital relay as a unit consisting of hardware and software, Sinusoidal wave based algorithms, Sample and first derivative (Mann and Morrison) algorithm, Fourier and Walsh based algorithms, Fourier Algorithm: Full cycle window algorithm, fractional cycle, window algorithm, Walsh function based algorithm, Least Squares based algorithms. Interpolation formulae, forward, backward and central difference interpolation, Numerical differentiation, Curve fitting and smoothing, Finite difference techniques, Differential equation based algorithms, Traveling Wave based Techniques, Digital Differential Protection of Transformers, Digital Line Differential Protection, Recent Advances in Digital Protection of Power Systems, Wide-area protection systems, concept of intelligent and adaptive protection schemes.

Suggested Books:

1. A.G. Phadke and J. S. Thorp, “Computer Relaying for Power Systems”, Wiley/Research studies Press, 2009
2. A.T. Johns and S. K. Salman, “Digital Protection of Power Systems”, IEEE Press,1999
3. Gerhard Zeigler, “Numerical Distance Protection”, Siemens Publicis Corporate Publishing, 2006
4. S.R. Bhide “Digital Power System Protection” PHI Learning Pvt.Ltd.2014

COURSE OUTCOMES:
At the end of the course, students will be able to:

CO1: Analyze the working and importance of different types of relays
CO2: Learn the importance of Digital Relays
CO3: Apply Mathematical approach towards protection
CO4: Learn to develop various Protection algorithms

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PC 4	EE6144	Distribution System Engineering	3	0	0	3

Module I:
Distribution system layout: modeling of components, sub-transmission network configurations, load profiles, selection of distribution class transformers, breakers, overhead vs underground cables, aerially bunched cables.

Distribution system power flow analysis and fault studies, Distribution system performance and operation, Distribution automation and control, Voltage drop calculation for distribution networks, Volt/ Var control in distribution systems, DSTATCOMs and DVRs, feeder reconfiguration for loss minimization and service restoration.

Module II:
Distribution system planning: Short term planning, Long term planning, Dynamic planning.

Distributed Generation: Standards, DG potential, Definitions and terminologies; current status and future trends, Technical and economic impacts. DG Technologies, DG from renewable and non-renewable energy sources, Optimization with DGs, Microgrids - islanded and grid connected modes, Demand side management.

Module III:
IT applications in distribution systems, smart meters, AMR, AMI, SCADA, State estimation, automation in billing, use of GPRS, consumer indexing, system reliability improvement, use of RMUs, auto reclosures, sectionalizers, islanding detection in microgrids.
Energy accounting and audit.

Suggested Books

1. Anthony J. Pansini"Electrical Distribution Engineering", CRC Press.
2. H Lee Willis, "Distributed Power Generation Planning and Evaluation", CRC Press.
3. James A Momoh, "Electric Power Distribution Automation Protection And Control" CRC Press
4. James J. Burke "Power distribution engineering: fundamentals and applications", CRC Press
5. T. Gonen, "Electric Power Distribution System Engineering", McGraw-Hill, 1986

Course Outcomes
At the end of the course, the students will be able to

CO1: learn the methodology of short-term and long-term planning of distribution system.
CO2: perform various calculation related to service area.
CO3: understand the technology and control of distributed generation.
CO4: design the primary and secondary distribution system with different load condition.
CO5: determine the power flow solution of distribution system with voltage control.
CO6: understand the automation and control of distribution systems.

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PE 2	EE6242	Switched Mode Power Conversion	3	0	0	3

Module-I

DC-TO-DC Converters: Series Controlled and Shunt Controlled Converters.
Switched Mode Power Converters: Buck Converter, Boost Converter and Buck-Boost Converters in CCM and DCM Operation
Isolated dc to dc Converters: Forward Converter, Push-Pull converter, Half and Full Bridge Converter, Fly-back Converter
Steady state analysis of derived DC-DC converters (Cuk, SEPIC, Quadratic)

Module-II

DC-TO-DC Converter – Dynamics, Dynamic models, Modeling approach, Averaged Model of the Converter, Small Signal Model of the Converter, Generalized State Space Model of the Converters, Dynamic Model of Converters Operating in DCM
Switched mode voltage regulator specifications, block diagram and transfer functions of hard switched converters in CCM and DCM modes.
Current Programmed Control of DC-to-DC Converters: Determination of Duty Ratio for Current Programmed Control for Buck Converter, Boost Converter and Buck-Boost Converter

Module-III

Soft Switching Converters: Resonant Load Converters, SMPS Using Resonant Circuit, Steady State Modeling of Resonant SMPS, Resonant Switch Converters, Buck Converter with Zero Current Switching, Boost Converter with Zero Voltage Switching
PWM Converters with Auxiliary Switch, ZVT /ZCT PWM Converters: Isolated and Non-isolated topologies with auxiliary switch; Auxiliary Resonant Commutated Pole Inverters: ZVT and ZCT concepts used for Inverters; Resonant DC Link Inverters

Text Books:

1. Ned Mohan et. al : Power Electronics ,John Wiley and Sons
2 . B K Bose : Modern Power Electronics and AC Drives, Pearson Edn (Asia)
3. M.H Rashid: Power Electronics, Pearson
4. M.H Rashid: Digital Simulation of Power Electronics, Pearson
5. R. W. Erickson and D. Maksimovic, 'Fundamental of Power Electronics', Springer International Edition, 2005.

COURSE OUTCOMES:

At the end of the course, the students will be able to

CO1: Understand the topology and operation of different types of switched mode converters
CO2: Understand the modeling of dc-dc converters and design the controllers
CO3: Current programmed control of dc-dc converters
CO4: Do steady state analysis and design of resonant SMPS

School/ Department: School of Electrical Sciences
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PE 2	EE6244	AI and Machine Learning	3	0	0	3

Module I
Artificial Neural Networks and Deep Learning
Neural Network representations, appropriate problems for neural network learning
Supervised Learning: Perceptrons, representational power of perceptrons, perceptron training rule, Gradient Descent and Delta rule, Multilayer perceptron and backpropagation algorithm
Linear Regression: Linear regression and prediction of continuous data values, Recurrent Neural Networks, RBFN
Unsupervised Learning: Competitive Learning, K-Means clustering, Hierarchical Clustering
Support Vector machines: Classification of data points using support vectors

Module II
Fuzzy Inference Systems:
Basic Concepts of Fuzzy Logic, Fuzzy vs Crisp Set, Linguistic variables, Membership Functions, Operations of Fuzzy Sets, Fuzzy If-Then Rules, Variable Inference Techniques, Defuzzification, Basic Fuzzy Inference Algorithm, Fuzzy Neural Network, System Identification using Fuzzy and Neural Networks

Module III
Genetic Algorithm:
Representing Hypothesis, Genetic operators, Population Evolution, Genetic programming,
Introduction to other evolutionary Algorithms like PSO, BFO etc

Text Books

1. Tom M Mitchell, Machine Learning, PHI LEARNING PVT. LTD-NEW DELHI, 2015
2. Ethem Alpaydin, Introduction to Machine Learning , The MIT Press, 3rd Edition, 2015
3. Simon Haykins, Neural Networks, Prentice Hall
4. Timothy Ross, Fuzzy Logic with Engineering Application- McGraw Hill Publishers

Reference Books

1. R. Duda, P. Hart, and D. Stork. "Pattern Classification", 2nd edition, Wiley Interscience, 2001.
2. C. M. Bishop. "Neural Networks for Pattern Recognition", Oxford University Press, 1995.
3. T. Hastie, R. Tibshirani and J. Friedman, "Elements of Statistical Learning: Data Mining, Inference and Prediction". Springer-Verlag, 2001.
4. T. Cover and J. Thomas. "Elements of Information theory", Wiley Interscience, 1991.
5. Golding, “Genetic Algorithms”, Addison Wesley
6. Junhong NIE & Derek Linkers, “Fuzzy Neural Control”, PHI

COURSE OUTCOME.
On successful completion, students will have the ability to
CO1 Apply the concepts of Neural network for pattern recognition andclassification
CO2 Apply Fuzzy logic principles to take decisions and design controllers
CO3 Apply GA principles for solving optimization problems

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Syllabus (Effective from 2023-24)

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 2	EE6246	Demand Side Management and Demand Response	3	0	0	3

COURSE OUTCOMES: After successful completion of this course, students shall be able to;

1. Learn special skills particularly on the load management and control strategies.
2. Learn the different schemes to find/calculate demand/load of particular sector.
3. Learn the working of different Instruments/Devices used to measure/calculate Demand/load of particular sector
4. Decide the true energy pricing for each particular site specifically

Module-I

Introduction and Concept of DSM-The concepts and methods of DSM-Load control, Energy efficiency, Load management; DSM planning, design, marketing; Impact assessment. Customer load control- Direct, Distributed, and Local control, Interruptible load; Configuration of control system for load control; Assessment of Impact on load shape.

Strategic Conservation and Load Management Technologies-Strategic conservation via improving building envelope, Air-conditioning, Lightning; Electric motor, and other industrial processes and equipment; Load shifting and load leveling through Thermal Energy Storage.

Module-II

Programs & Incentives for Customers, Customer Incentives, Program Marketing Design and Penetration-Type of incentives and programs, Program design; Use of Analytic Hierarchical Process for assessment of Customer Acceptance and Program penetration.

Technology Assessment for Demand Response (DR): Framework for technology assessment of Demand Response, Demand response for Commercial facilities, Comparative analysis of available communication technologies for DR, Demand Response strategies based on End-Use load types, Standards for DR, Measurement & Verification for DR.

Module-III

Assessment of Impact on System Load Shape Energy Audit and assessment of customers' load shape for different customer groups; Impact of DSM programs on load shapes in customer groups, Categorized in economic sub sectors, and by geographical location, Cost/Benefit Analysis and Feasibility of DSM Program DSM program costing and Load Shape Impact on system; DSM program cost/benefit and Feasibility; Environmental benefits.

Potential benefits of demand response, enabling smart technologies for demand response, control devices for demand response, Monitoring and communication system. Demand response for Electric
Vehicles.

Reference Books:

1. Demand Side Management, Jyothi Prakash, TMH Publishers.
2. Energy management hand book by W.C.Turner, John Wiley and sons
3. Energy Demand – Analysis, Management and Conservation, Ashok V. Desai, WileyEastern, 2005.
4. Demand Response in Smart Grids, Pengwei Du, Ning Lu, Haiwang Zhong, Springer, 2019.

PE 3	EE6248	Advanced DSP	3	0	0	3

MODULE-I

Classification of Signals: Multichannel and Multidimensional Signals, Continuous-Time Versus Discrete-Time Signals, Continuous-Valued Versus Discrete-Valued Signals, Deterministic Versus Random Signals, Concept of frequency in Continuous-Time and Discrete-Time Signals

Analysis of Discrete-Time LTI Systems:

Resolution of a Discrete-Time Signal into impulses, Response of LTI Systems to Arbitrary Inputs: The convolution sum, Causal LTI Systems, systems with Finite-Duration and Infinite-Duration Impulse Response, Recursive and Non-Recursive Discrete-Time Systems, LTI Systems characterized by Constant Coefficient Difference Equations

Correlation of Discrete-Time Signals:

Cross-correlation and Auto-Correlation Sequences, Properties of Cross-correlation and Auto-Correlation Sequences, Correlation of Periodic Sequences, Input-Output Correlation Sequences

MODULE-II

Transforms used in Signal Processing:

Discrete Fourier Transform, Its Properties, Use of DFT in Linear Filtering

Discrete Cosine Transform: Forward DCT, Inverse DCT, DCT as an Orthogonal Transform

Fast Fourier Transform: Divide and Conquer Approach to Computation of DFT, Radix-2 and Radix-4 FFT

Brief introduction to Short time Fourier Transform, Discrete Wavelet Transform, S-Transform and their applications

MODULE-III

Adaptive Signal Processing:

Least Mean Square Algorithm and its variants, Properties of LMS Algorithm, Recursive Least Square Algorithm and its variants, Kalman Filter

Application of Adaptive Signal Processing to Power System

Time Series Prediction:

Nature of Time Series Data, AutoRegressive Moving Average (ARMA) Models, AutoRegressive Integrated Moving Average (ARIMA) Models for Forecasting & Estimation

Course Outcomes:

Upon completion of the course, the students will demonstrate the ability to:

CO1 Learn about analysis and correlation of discrete-time signals

CO2 Learn about different Transforms used in signal processing

CO3 Learn about different estimation techniques

CO4 Know about time series prediction

TEXT/ REFERENCE BOOKS:

1. J. G. Proakis and D. G. Manolakis, “Digital Signal Processing”, Fourth Edition, Pearson
2. Simon Haykin, “Adaptive Filter Theory”, Fourth Edition, Pearson
3. A. Nagoor Kani, “Discrete-Time Signal Processing”, Prentice Hall
4. Alan V. Oppenheim, Ronald W. Schafer, “Discrete-Time Signal Processing”, Prentice Hall
5. S. Mallat, “A wavelet Tour of Signal Processing: The sparse way: Academic Press, 2010

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Syllabus (Effective from 2023-24)

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 3	EE6250	Smart Grid Technology	3	0	0	3

Module-I:
Evolution of Electric Power Grid, introduction to smart Grid, Concept, definitions, architecture and functions of Smart Grid. Need of Smart Grid. Difference between conventional & smart grid. Opportunities & Challenges of Smart Grid, Introduction to Smart Meters, Real Time Pricing, Smart Appliances. Automatic Meter Reading(AMR). Outage Management System(OMS). Home & Building Automation, Substation Automation, Feeder Automation, Smart Sensors, Phase Shifting Transformers, Volt/VAr control, High Efficiency Distribution Transformers

Module-II:
Geographic Information System(GIS). Intelligent Electronic Devices(IED) & their application for Monitoring & Protection, Storage systems including Battery, SMES, Pumped Hydro. Compressed Air Energy Storage. Phasor Measurement Units (PMU), Wide Area Measurement System(WAMS), Wide-Area based Protection and Control Micro-grid concepts, evolution of microgrid, need and application, Issues of Interconnection. Protection & control systems for micro-grid. Variable speed wind generators, fuel-cells, micro-turbines. Captive power plants, Integration of renewables and issues involved, Advantages and disadvantages of Distributed Generation.

Module-III:
Power Quality & EMC in smart Grid. Power Quality issues of Grid connected Renewable Energy Sources. Power Quality Conditioners for micro-grid. Web based Power Quality monitoring, Power Quality Audit. Advanced Metering Infrastructure(AMI). Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN), Energy Management Systems (SCADA).

Suggested Books:
1. Ali Keyhani, “Design of Smart power grid renewable energy systems”, Wiley IEEE,2011.
2. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press, 2009.
3. Stuart Borlase, “ Smart Grid: Infrastructure Technology and solutions “ CRC Press.
4. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley.
5. Andres Carvallo, John Cooper, “The Advanced Smart Grid: Edge Power Driving Sustainability: 1”, Artech House Publishers July 2011
6. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert “Substation Automation (Power Electronics and Power Systems)”, Springer

COURSE OUTCOMES:
After successfully completing this course a student will able to:
CO 1: Understand the fundamental element of the smart grid
CO 2: Explain various communication, networking, and sensing technologies involved in smart grid
CO 3: Explain various integration aspects of conventional and non-conventional energy sources.
CO 4: Explain distributed generation coordination including monitoring of smart grid using modern communication infrastructure
CO 5: Analyze Micro-grid as a hybrid power system with advantages and challenges in future.
CO 6: Be able to apply this knowledge in analysis and problem solving of smart grid architectures needs and challenges

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Syllabus (Effective from 2023-24)

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 3	EE6252	Power System Planning	3	0	0	3

Module I:
Basic Elements Power System Planning: Various issues relating to power system planning: an overview of the generation, transmission, and distribution aspects of planning, Long term, and short- term planning; Growth and development of the Electrical Power Industry Global and Indian scenario, 5-year plans. Indian power industry and current developments, Role of key institutions in power system planning in the Indian context.

Module II:
Generation Planning: Load forecasting, importance, and various methodologies, power system reliability, indices, Markov two-state model for generating systems availability, upgradation of old power stations; technical and economic issues
Transmission Line Planning: Selection of voltage levels and type of system (EHV AC or HVDC), Corona losses and Radio interference, Right –of-way requirements, Routing of transmission lines, methods, Line congestion in deregulated systems, and their minimization Grid issues and regulations. Transmission line reliability evaluation
Distribution Planning: Distribution systems; ring and radial systems, loss minimization by reconfiguration; substation location and planning, Distributed automation and loss minimization in feeders by reactive power compensation: series and shunt compensation, Improved billing Strategies.

Module III:
Miscellaneous issues: Deregulation of power systems, energy conservation and audits, Security and contingency analysis

References

1. Pabla. A.S. " Electrical Power Distribution Systems ", Tata-McGraw Hill, New Delhi.
2. National Power Plan (1985 -2000AD) Central Electricity Authority, Ministry of Power , Govt. of India,, New Delhi
3. Sullivan W. and Wayne, W, "Fundamentals of Forecasting" , Reston Publishing Company. Virizinia
4. Billington, Roy and Allen , R. N. " Reliability Evaluation of Power Systems", Pitman, London (U.K.)
5. Weedy, B.M. " Electrical Power Systems" John Wiley and Sons, Singapore

COURSE OUTCOMES:
At the end of the course, students will be able to:
CO1: Gain knowledge on the generation, transmission, and distribution aspects of planning,
the Indian power industry, and current developments
CO2: Gain knowledge on Generation Planning, Transmission Line Planning, Distribution
CO3: Gain knowledge on energy conservation and audits, Security, and contingency analysis

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 3	EE6254	High Voltage Engineering	3	0	0	3

Course Objective:
The objective of a high voltage technique course is to provide participants with a comprehensive understanding of the principles, practices, and safety considerations associated with high voltage systems. The course aims to equip individuals with the knowledge and skills necessary to work with and manage high voltage equipment and systems safely and effectively.

Module I
Breakdown in Gases: Ionization processes, Breakdown in Uniform field: Townsend's mechanisms, breakdown in electronegative gases, Streamer Theory of Gaseous breakdown, Paschen's Law, breakdown in electronegative gases. Breakdown of gases in non-uniform field: effect of space charge, corona for positive and negative polarities. Breakdown phenomena under AC voltage and impulse voltage.

Lightning Phenomenon: Charge formation in clouds: Wilson's theory, Simpson's theory; Mechanism of lightning: stepped leader, return stroke, multiple strokes.

Module II
Breakdown in Liquids: Classification of liquids, breakdown in pure liquids, breakdown in commercial liquids.

Breakdown in Solids: Intrinsic breakdown, Electromechanical breakdown, Thermal breakdown, Treeing and tracking.

Over-voltages in Power Systems and Insulation Co-ordination: External over-voltages, internal over-voltages.

Module III
Generation of High Voltages: Generation of high direct voltages: Rectifier circuits, voltage doubler and multiplier circuits, cascade circuits; Generation of high alternating voltages: Generation of impulse voltages: Characteristics of impulse and switching surge voltage, analysis of single stage impulse generator circuit, constructional features of multi-stage impulse generators. Generation of Switching surges.

High Voltage Testing of Power System Equipments: Testing of insulators, bushings, circuit breakers, transformers, surge arrestors.

Books:

1. Kuffel J., Kuffel E., and Zaengl W.S., "High Voltage Engineering fundamentals", 2 nd edition, Newness(Oxford, Boston).
2. Naidu, M.S. and Kamaraju, V.," High Voltage Engineering ",4th, edition, Tata McGraw-Hill, New Delhi.
3. Abdel-salam M., Anis H. and , Abdel-salamani," High-Voltage Engineering: Theory and Practice", 2nd edition, CRC Press
4. Kind D. and Freser K.," High Voltage Test Techniques",2nd edition, Newnes (Oxford, Boston).
5. Ray S.," An introduction to High Voltage Engineering", Prentice Hall India, New Delhi.

OE 1	Any One from the List of OE 1 (Appendix-I)	3	0	0	3

Refer Appendix-I for detailed Syllabus.

PR 1	EE6642	Project (Specialization Related)	0	0	4	2

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

LC 3	EE6542	Renewable Energy Lab	0	0	4	2

Lists of Experiments

Sl. No.	Name of the Experiment
1.	Calculate the efficiency of solar PV module of your laboratory.
2.	Calculate the fill factor of a solar PV cell.
3.	Develop the P-V and I-V graphs at different insolations / irradiances.
4.	Develop the P-V and I-V graphs at different insolations/irradiances.
5.	Realise the hot spot effect of your laboratory solar PV module.
6.	Calculate the performance parameter of the solar cooker system of your laboratory.
7.	Study and performance analysis of wind power system under various loads.
8.	Study the supply side and load side power factors of a solar PV system.
9.	Study the harmonics present in grid tied solar PV system.
10.	Develop the power curve of wind turbine at various wind velocities.
11.	Study of various softwares related to laboratory experiments
12.	Simulation of power flow of a standalone PV system with a DC load and battery
13.	Simulation of power flow of a standalone PV system with a AC load and battery
14.	Develop the energy density of various energy crops and residues.
15.	Calculate the GCV and NCV of a wood specimen.

COURSE OUTCOMES:

At the end of the course, the student will be able to

CO1: Gain knowledge of different renewable sources and its energy content.
CO2: Perform experiments to measure energy content.
CO3: Develop the characteristics and performance of renewable technologies especially devoted to production of electricity.
CO4: Design various loads and characterise its better performance.

AC 2	Any One from the List of AC 2 (Appendix-I)	2	0	0	0

Refer Appendix-I for detailed Syllabus.

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

3rd Semester

PE 4	EE7241	Grid Integration of Renewable Sources	3	0	0	3

MODULE-I

Introduction to distributed generation/Micro Grid: General introduction to the concept of distributed generation, Standalone System, Integration of distributed renewable generation into the electricity system (Current status, challenges and prospects) and its impacts on the electrical system.

Network topologies with distributed generation: Description of the different network topologies where distributed renewable generation (Wind, Solar, Hydro, Tidal power) can be connected. Principles of design, operation.

MODULE-II

Power system Performance:

Impact of distributed generation on power system in terms of changes taking place and severity imposed, power quality issues, voltage quality issues, design of distributed generation.

Impact of distributed generation on power system in terms of overloading and losses, radial distribution networks, redundancy and meshed operation, losses, increasing the hosting capacity.

MODULE-III

Control of standalone system and Grid connected system (Voltage and frequency control). Phase Locked Loop, Islanding and reconnecting. Primary frequency control in large systems, Fault ride through.

Transmission system operation: Fundamental operation, Frequency control, Balancing and Reserves, Prediction of production and consumption, Restoration, Voltage stability, Angular stability.

Textbooks:

1. Bollen M.H.J., Hassan F., Integration of distributed generation in the power system. IEEE Press Series on Power Engineering. Wiley. Hoboken 2011.
2. Jenkins N., Allan R., Crossley P., Kirschen D., Strbac G., Embedded generation. IEE Power and Energy Series 31. London, 2000.
3. Jenkins N., Ekanayake J.B., Strbac G., Distributed generation. IET Renewable Energy Series 1. London 2010.
4. Keyhani A., Marwali M.N., Dai M., Integration of green and renewable energy in electric power systems. Wiley. Hoboken 2010.

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 4	EE7243	Electric Power System Market	3	0	0	3

Module 1:
Introduction to power system operation and planning problems - economic dispatch, unit commitment, optimal power flow, security constrained optimization, maintenance scheduling, expansion planning, fundamentals of restructured system, market architecture.

Module 2:
Fundamentals of Economics, load elasticity, social welfare maximization, day ahead and real time market clearing, day ahead security constrained unit commitment, locational marginal prices, transmission congestion management, financial transmission rights. Ancillary service management, optimal bidding, Risk assessment, Hedging.

Module 3:
Transmission pricing, tracing of power, standard market design, distributed generation in restructured markets, loss allocation, expansion planning under restructured environment, Market power, US and European market evolution, developments in India, IT applications in restructured markets, Working of restructured power systems, PJM, recent trends in Restructuring

Suggested Books:

1. Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheble, “Power Generation, Operation and Control” 3rd edition, Wiley
2. Daniel S. Kirschen and Goran Strbac, “Fundamentals of Power System Economics” 1st edition, Wiley
3. Lorrin Philipson, H. Lee Willis, “Understanding electric utilities and de-regulation”, Marcel Dekker Pub.,1998.
4. Steven Stoft, “Power system economics: designing markets for electricity”, John Wiley and Sons, 2002.
5. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen, “Operation of restructured power systems”, Kluwer Academic Pub., 2001.
6. Mohammad Shahidehpour, MuwaffaqAlomoush, “Restructured electrical power systems: operation, trading and volatility”, Marcel Dekker.

Course Outcomes:
At the end of the course, students will be able to:

CO1: Describe various types of regulations in power systems.

CO2: Identify the need of regulation and deregulation.

CO3: Define and describe the Technical and Non-technical issues in Deregulated Power Industry.

CO4: Identify and give examples of existing electricity markets.

CO5: Classify different market mechanisms and summarize the role of various entities in the market.

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 4	EE7245	FACTs and Customer Power Devices	3	0	0	3

Module I:
Flexible AC Transmission System: Transmission inter connections, flow of power in ac systems, loading capability, dynamic stability considerations, basic types of FACTS controllers.

Module II:
Static Shunt and Series Compensators: Objectives of shunt compensation, Static VAR compensators (SVCs), STATCOM configuration, Characteristics and control, Comparison between STATCOM and SVC.Objectives of series compensation, Variable Impedance type series compensators, switching converter type series compensators, external control for series reactive compensators.

Module III:
Power Flow Control Techniques: Principle of operation and characteristics, independent active and reactive power flow control, comparison of UPFC with the series compensators and phase angle regulators, Principle of operation, characteristics and control aspects of IPFC.
Custom Power Devices: Introduction to custom power devices, DSTATCOM and DVR operating principles, Applications of DSTATCOM and DVRs in Distribution Systems.

Suggested Books:

1. Hingorani ,L.Gyugyi, ‘ Concepts and Technology of Flexible AC transmission system’, IEEE Press New York, 2000.
2. K.R.Padiyar, “FACTS controllers in power transmission and distribution”, New Age International Publishers, Delhi, 2007.

COURSE OUTCOMES (CO’S)

At the end of the course, the students will be able to

CO1: gain knowledge on flexible AC transmission system criteria, advantages, and control parameters.
CO2: gain knowledge on various compensation techniques for control of FACTs devices.
CO3: gain knowledge on various practices being followed in the real system scenario.

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 4	EE7247	Power Quality	3	0	0	3

Module I:

Electric Power Quality Phenomena: Impacts of power quality problems on end users, Power quality standards, power quality monitoring.

Power Quality Disturbances: Transients, short duration voltage variations, long duration voltage variations, voltage imbalance, wave-form distortions, voltage fluctuations, power frequency variations, power acceptability curves.

Module II:

Power Quality Problems in Power Systems: Poor load power factor, loads containing harmonics, notching in load voltage, dc offset in loads, unbalanced loads, disturbances in supply voltage.

Transients: Origin and classification- capacitor switching transient-lighting-load switching-impact on users, Protection and mitigation of transients.

Module III:

Harmonics: Harmonic distortion standards, power system quantities under non sinusoidal conditions-harmonic indices-source of harmonics-system response characteristics-effects of harmonic distortion on power system apparatus –principles for controlling harmonics, reducing harmonic currents in loads, filtering, modifying the system frequency response- Devices for controlling harmonic distortion, inline reactors or chokes, zigzag transformers, passive filters, active filters.

Power Quality Conditioners: Shunt and series compensators, Distribution STATCOMS (DSTATCOMS) and Dynamic Voltage Restorers (DVRs), Rectifier supported DVR, DC Capacitor supported DVR, DVR Structure, Voltage Restoration – Series Active Filter – Unified power quality conditioners.

Suggested Books:

1. Ghosh Arindam and Ledwich Gerard, ‘Power quality enhancement using custom power devices’ Springer.
2. Arrillaga J., Watson N. R. and Chen S., ‘Power System Quality Assessment’ Wiley.
3. Caramia P, Carpinelli G and Verde P, ‘Power quality indices in liberalized markets’ – Wiley
4. Angelo Baggini ‘Handbook of Power Quality’ – Wiley.
5. G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition)
6. R.C. Duggan, ‘Power Quality’, TMH Publication, 2002

COURSE OUTCOMES (CO’S)

At the end of the course, students will be able to:

CO1: gain knowledge on issues of power quality and factors governing it.

CO2: gain knowledge on impacts of poor power quality on the system and the consumers.

CO3: gain knowledge on harmonics (cause, effect and compensating techniques).

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Syllabus (Effective from 2023-24)

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

PE 4	EE7249	EHVAC Transmission	3	0	0	3

Course Objective:
To expose students to the advanced concepts in EHVAC transmission systems, and their design, analysis and control.

Module I
Introduction: Overview of electrical power transmission at high Voltages; EHV AC Transmission line trends; Advantages and issues with EHV AC transmission.
EHV AC transmission system line parameters: Resistance; Bundle conductor systems; Inductance and capacitance of E.H.V. lines; Positive, negative and zero sequence impedances; Line parameters for Modes of Propagation.
Surface voltage gradient and corona: Surface voltage gradient; Gradient factor and their use; Distribution of voltage gradient on sub-conductors of the bundle. Power loss due to corona; Audio noise and Radio noise and their computation as well as measurement; Limits prescribed in standards.

Module II
Electrostatic and electromagnetic fields: Calculations of electrostatic and magnetic fields; Their effect on biological organisms and human beings and limits of exposure, Electrostatic and electromagnetic induction.
Voltage control and Stability in EHV lines: No load voltage; Charging currents at power frequency; voltage control; Shunt and series compensation; Stability in EHV grids and systems.
Over voltages in EHV systems: Temporary, lightning and switching over voltages; Over voltage computation; Shielding of transmission lines against lightning; Insulation characteristics of long air gaps; Protection of station apparatus and transmission lines against over voltages.

Module III
EHV Transmission Line Design: EHV AC transmission line design examples based on steady-state limits and transient over voltages.
Miscellaneous Topics: Mechanical vibration of bundled conductors; temperature rise of conductors; Ceramic and non-ceramic types insulators and their performance in polluted environments; EHV substations - AIS and GIS and Electrical Equipment.

Books:

1. R. D. Begamudre, Extra High Voltage AC Transmission Engineering, Fourth Edition, New Age International Publishers, New Delhi, 2011.
2. Transmission Line Reference Book 345 kV and Above, Electrical Power Research Institute (EPRI), USA, 1982.
3. Kundur, P. and Balu, N.J. and Lauby, M.G., Power system stability and control, McGraw-Hill.
4. Edited by Turan Gonen, Electrical Power Transmission System Engineering: Analysis and Design, Second Edition, CRC Press, Boca Raton, 2009.
5. F. Kiessling, P. Nefzger, J. F. Nolasco, and U. Kaintzyk, Overhead Power Lines: Planning, Design, Construction, Springer, Berlin, 2002.
6. Miller T. J. E., Reactive Power Control in Electric Systems, John Wiley and Sons.
7. Ragaller, K. (ed.), Surges in High Voltage Networks

PR 2	EE7641	Dissertation (Phase-I)	0	0	24	12

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Syllabus (Effective from 2023-24)

School/ Department: School of Electrical Sciences
Course: M. Tech., Programme: Power Systems Engineering (PSE),
Duration: 2 years (Four Semesters)

4th Semester

PR 3	EE7642	Dissertation (Phase-II)	0	0	32	16