FRANCIS XAVIER ENGINEERING COLLEGE

AUTONOMOUS INSTITUTION

ACCREDITED BY NBA

ISO 9001:2015 Certified | DST-FIST Supported Institution

Recognized under Section 2(f) & 12(B) of the UGC Act, 1956

Vannarpettai, Tirunelveli - 627003, Tamil Nadu

CURRICULUM & SYLLABI

M. E - Power Systems Engineering (Regulation 2019)

VISION

"To be a Centre of Excellence for Technology transformation in the field of Electrical and Electronics Engineering"

MISSION

1. **To empower the vibrant young leaders with technical skills and knowledge in the field of technology**
2. **To facilitate the industries to adopt effective solutions in the field of Electrical and Electronics Engineering through consultancy**
3. **To transform technology for rural needs.**

FRANCIS XAVIER ENGINEERING COLLEGE

TIRUNELVELI

PROGRAM EDUCATIONAL OBJECTIVES (PEOS)

i. To prepare the students to have career in the electrical power industry/research organization/teaching.

ii. To provide good foundation in mathematics and computational technology to analyze and solve problems encountered in electrical power industry.

iii. Pursue lifelong learning and continuous improvement of their knowledge in the electrical power industry.

iv. To understand the national and global issues related to the electrical power industry and to be considerate of the impact of these issues on the environment and within different cultures.

v. Apply the highest professional and ethical standards to their activities in the electrical power industry.

vi. To provide the students with knowledge to be involved with the technology advancements and future developments in power generation, control and management as well as with alternate and new energy resources.

PROGRAM OUTCOMES (POs)

On successful completion of the programme,

1. Graduates will be able to demonstrate the principles and practices of the electrical power industry regarding generation, transmission, distribution and electrical machines and their controls.
2. Graduates will be able to apply their knowledge of electrical power principles, as well as mathematics and scientific principles, to new applications in electrical power.
3. Graduates will be able to perform, analyze, and apply the results of experiments to electrical power application improvements.
4. Graduates will be able to look at all options in design and development projects and creativity and choose the most appropriate option for the current project.

5. Graduates will function effectively as a member of a project team.
6. Graduates will be able to identify problems in electrical power systems, analyze the problems, and solve them using all of the required and available resources.
7. Graduates will be able to effectively communicate technical project information in writing or in personal presentation and conversation.
8. Graduates will be engaged in continuously learning the new practices, principles, and techniques of the electrical power industry.
9. Graduates will work on application software packages for power system analysis and design.
10. Graduates will develop indigenous software packages for power system planning and operational problems of utilities.

MAPPING OF PROGRAMME EDUCATIONAL OBJECTIVES WITH PROGRAMME OUTCOMES

Program Educational Objective	**PROGRAMME OUTCOMES**									
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
i	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
ii	**X**	**X**	**X**	**X**	**X**			**X**	**X**	**X**
iii								**X**		
iv	**X**		**X**	**X**		**X**			**X**	**X**
v					**X**		**X**	**X**	**X**	**X**
vi	**X**	**X**	**X**	**X**		**X**		**X**	**X**	**X**

FRANCIS XAVIER ENGINEERING COLLEGE, TIRUNELVELI

M. E –POWER SYSTEMS ENGINEERING

CHOICE BASED CREDIT SYSTEM

I TO IV SEMESTERS CURRICULUM & SYLLABI

SEMESTER - I

FIRST SEMESTER							
Code No.	**Course**	**Category**	**L**	**T**	**P**	**C**	**H**
19MA1253	Applied Mathematics for Electrical Engineers	BS	3	1	0	4	4
19PS1601	Analysis and Computation of Electromagnetic Transients in Power Systems	PC	3	0	0	3	3
19PS1602	Power System Modeling and Analysis	PC	3	1	0	4	4
19PS1603	Power System Operation and Control	PC	3	0	0	3	3
19PE1605	System Theory	PC	3	1	0	4	4
	Professional Elective I	PE	3	0	0	3	3
19PS1611	Power System Simulation Laboratory	PC	0	0	4	2	4
		TOTAL	**18**	**3**	**4**	**23**	**25**

SECOND SEMESTER							
Code No.	**Course**	**Category**	**L**	**T**	**P**	**C**	**H**
19PS2601	Digital Protection for Power System	PC	3	0	0	3	3
19PS2602	Power System Dynamics and stability	PC	3	0	0	3	3
19PS2603	Restructured Power System	PC	3	0	0	3	3
19PE2705	Flexible AC Transmission Systems	PC	3	0	0	3	3
	Professional Elective II	PE	3	0	0	3	3
	Professional Elective III	PE	3	0	0	3	3
19PS2611	Advanced Power System Simulation Laboratory	PC	0	0	4	2	4
19PS2911	Technical Seminar	EEC	0	0	2	1	2
		TOTAL	**18**	**0**	**6**	**21**	**24**

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THIRD SEMESTER							
Code No.	**Course**	**Category**	**L**	**T**	**P**	**C**	**H**
	Professional Elective IV	PE	3	0	0	3	3
	Professional Elective V	PE	3	0	0	3	3
	Professional Elective VI	PE	3	0	0	3	3
19PS3911	Project Work Phase I	EEC	0	0	12	6	12
		TOTAL	**09**	**0**	**12**	**15**	**21**

FOURTH SEMESTER							
Code No.	**Course**	**Categor y**	**L**	**T**	**P**	**C**	**H**
19PS4911	Project Work Phase II	EEC	0	0	24	12	24
		TOTAL	**0**	**0**	**24**	**12**	**24**

Total Credits :71

Code No.	**Course**	**L**	**T**	**P**	**C**
	PROFESSIONAL ELECTIVES				
PROFESSIONAL ELECTIVE I- SEMESTER I					
19PE1603	Modeling and Analysis of Electrical Machines	3	0	0	3
19PE1604	Solar and Energy Storage Systems	3	0	0	3
19PE2704	Soft Computing Techniques	3	0	0	3
		3	0	0	3
PROFESSIONAL ELECTIVE II&III - SEMESTER II					
19PE3707	Smart Grid	3	0	0	3
19PE1602	Analysis and Design of Power Converters and Inverters	3	0	0	3
19PS2701	Power System Reliability	3	0	0	3
19PE3701	High Voltage Direct Current Transmission	3	0	0	3
19PE2709	Distributed Generation and Micro grid	3	0	0	3
19PS2702	Industrial Power System Analysis and Design	3	0	0	3
PROFESSIONAL ELECTIVE IV, V & VI - SEMESTER III					
19PS3701	Electrical Distribution System	3	0	0	3

Code No.	Course	L	T	P	C
19PS3702	Energy Management and Auditing	3	0	0	3
19PE3703	Wind Energy Conversion Systems	3	0	0	3
19PE3705	Electric and Hybrid Vehicles	3	0	0	3
19PE2707	Electromagnetic Interference and Compatibility	3	0	0	3
19PE2703	Control System Design for Power Electronics	3	0	0	3
19PS3703	Principles of Electric Power Transmission	3	0	0	3
19PS3704	Advanced Power System Dynamics	3	0	0	3
19PS3705	Design of Substations	3	0	0	3

19MA1253	APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS	L	T	P	C
		3	1	0	4

COURSE OBJECTIVES:

- The main objective of this course is to demonstrate various analytical skills in applied mathematics and extensive experience with the tactics of problem solving and logical thinking applicable for the students of electrical engineering.
- This course also will help the students to identify, formulate, abstract, and solve problems in electrical engineering using mathematical tools from a variety of mathematical areas, including matrix theory, calculus of variations, probability, linear programming and Fourier series.

PRE-REQUISITE:

UG level Mathematics

UNIT I MATRIX THEORY 12

Cholesky decomposition-Generalized Eigenvectors-Canonical basis-QR Factorization-Least squares method-Singular value decomposition

UNIT II CALCULUS OF VARIATIONS 12

Concept of variation and its properties–Euler's equation–Functional dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries–Isoperimetric problems-Direct methods : Ritz and Kantorovich methods.

UNIT III PROBABILITY AND RANDOM VARIABLES 12

Probability–Axioms of probability–Conditional probability–Baye's theorem -Random variables-Probability function–Moments–Moment generating functions and their properties–Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions–Function of a random variable.

UNIT IV LINEAR PROGRAMMING 12

Formulation–Graphical solution–Simplex method–Big M method-Two phase method-Transportation and Assignment models.

UNIT V FOURIER SERIES **12**

Fourier trigonometric series: Periodic function as power signals–Convergence of series–Even and odd function : Cosine and sine series–Non periodic function : Extension to other intervals-Power signals : Exponential Fourier series –Parseval's theorem and power spectrum–Eigen value problems and orthogonal functions–Regular Sturm - Liouville systems–Generalized Fourier series.

TOTAL PERIODS : 60

REFERENCES :

1. Andrews L.C. and Phillips R.L., "Mathematical Techniques for Engineers and Scientists", Prentice Hall of India Pvt. Ltd., New Delhi, 2005.
2. Bronson, R. "Matrix Operation", Schaum's outline series, 2ndEdition, McGraw Hill, 2011.
3. Elsgolc, L. D. "Calculus of Variations", Dover Publications, New York, 2007.
4. Johnson, R.A., Miller, I and Freund J., "Miller and Freund's Probability and Statistics for Engineers", Pearson Education, Asia, 8thEdition, 2015.
5. O'Neil, P.V., "Advanced Engineering Mathematics", Thomson Asia Pvt. Ltd., Singapore, 2003.
6. Taha, H.A., "Operations Research, An Introduction",9^{th} Edition, Pearson education, New Delhi, 2016.

WEB RESOURCES:

- **https://nptel.ac.in/courses/111102012/**

COURSE OUTCOMES:

After completing this course, students should demonstrate competency in the following skills:

CO No	COURSE OUTCOMES
CO101.1	Apply various methods in matrix theory to solve system of linear equations.
CO101.2	Maximizing and minimizing the functional that occur in electrical engineering discipline.
CO101.3	Computation of probability and moments, standard distributions of discrete and continuous random variables and functions of a random

variable.

CO101.4 Could develop a fundamental understanding of linear programming models, able to develop a linear programming model from problem description, apply the simplex method for solving linear programming problems.

CO101.5 Fourier series analysis and its uses in representing the power signals

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO101.1	**3**	**3**								**2**
CO101.2	**3**	**3**								**2**
CO101.3	**3**	**3**								**2**
CO101.4	**3**	**3**								**2**
CO101.5	**3**	**3**								**2**

1 ❼ Low 2 ❼ Medium 3 ❼ High

19PS1601

ANALYSIS AND COMPUTATION OF ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To understand the various types of transients and its analysis in power system.
- To learn about modeling and computational aspects transient's computation
- To understand the parameters and modeling of underground cables.
- To understand the modeling of power system for transient over voltages.
- Electromagnetic Transient Program (EMTP).

PRE-REQISITE:

- Electromagnetic Theory
- Electrical Transients

- Power System Analysis
- Power Quality

UNITI REVIEW OF TRAVELLING WAVE PHENOMENA 9

Lumped and Distributed Parameters–Wave Equation–Reflection, Refraction, Behaviour of Travelling waves at the line terminations –Lattice Diagrams – Attenuation and Distortion.

UNITII LIGHTNING, SWITCHING AND TEMPORARY OVER VOLTAGES 9

Lightning over voltages: interaction between lightning and power system- ground wire voltage and voltage across insulator; switching over voltage : Short line or kilometric fault, energizing transients – closing and re-closing oflines, methods of control; temporary over voltages : line dropping, load rejection; voltage induced by fault; very fast transient over voltage (VFTO).

UNITIII PARAMETERS AND MODELING OF OVER HEADLINES 9

Review ofline parameters for simple configurations : series resistance, inductance and shunt capacitance; bundle conductors : equivalent GMR and equivalent radius; modal propagation in transmission lines : modes on multi-phase transposed transmission lines, α-β-0 transformation and symmetrical components transformation, modal impedances; analysis of modes on un transposed lines; effect of ground return and skin effect; transposition schemes; introduction to frequency - dependent line modeling.

UNITIV PARAMETERS AND MODELING OF UNDERGROUND CABLES 9

Distinguishing features of under ground cables: technical features, electrical parameters, over head lines versu under ground cables; cable types; series impedance and shunt admittance of single-core self – contained cables, impedance and admittance matrices for three phase system for med by three single – core self-contained cables; approximate formulas for cable parameters.

UNITV COMPUTATION OF POWER SYSTEM TRANSIENTS 9

Digital computation of line parameters : Need ofline parameter evaluation programs, salient features of a typical line parameter evaluation program; constructional feature soft hat affect transmission line parameters; line parameters for physical and equivalent phase conductors elimination of ground wires bundling of conductors; principle of digital computation of transients : features and capabilities of electromagnetic transients program; steady state and time step solution modules : basic solution methods; case studies on simulation of various types of transients.

TOTAL : 45 PERIODS

REFERENCES

1. Allan Greenwood, "Electrical Transients in Power System", Wiley & Sons Inc. New York, 1991.
2. R. Ramanujam, "Computational Electromagnetic Transients: Modeling, Solution Methods and Simulation", I.K. International Publishing House Pvt. Ltd, New Delhi, 2014.
3. Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004

WEB RESOURCES:

- https://www.researchgate.net/publication/224716926_Computation_of_power_system_transients_Overview_and_challenges
- https://onlinelibrary.wiley.com/doi/10.1002/9781118694190.ch1
- http://www.srmvalliammai.ac.in/questionbank-meps.html
- https://epd.wisc.edu/courses/analysis-of-transients-in-power-systems/

COURSE OUTCOMES:

CO No	COURSE OUTCOMES
CO102.1	Able to model overhead lines, cables and transformers.
CO102.2	Able to analyze power system transients.

CO102.3 Able to modeling of underground cables.

CO102.4 Able to modeling of power system for transient over voltages.

CO102.5 Familiarize in using Electromagnetic Transient Program

POs Vs COs MAPPING:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO102.1	3	1										
CO102.2	2	3										
CO102.3	3	1	3		2							
CO102.4	2	2	3		3				2		2	
CO102.5	2	3	3		3				2		3	

1 ❼ Low 2 ❼ Medium 3 ❼ High

19PS1602	**POWER SYSTEM MODELLING AND ANALYSIS**	**L**	**T**	**P**	**C**
		4	**0**	**0**	**4**

OBJECTIVES:

- To discuss different techniques dealing with sparse matrix for large scale power systems.
- To explain different methods of power flow solutions.
- To solve optimal power flow problem.
- To analyze various types of short circuit faults analysis and understand the consequence of different type of faults.
- To demonstrate different numeric al integration methods and factors influencing transient stability.

PRE-REQISITE:

- Transmission and Distribution
- Power Plant Engineering
- High Voltage Engineering
- Power System Analysis

UNIT I SOLUTION TECHNIQUE 9

Sparse Matrix techniques for large scale power systems: Optimal ordering schemes for preserving sparsity. Flexible packed storage scheme for storing matrix as compact arrays – Factorization by Bi factorization and Gauss elimination methods; Repeat solution using Left and Right factors and L and U matrices.

UNIT II POWER FLOW ANALYSIS 9

Power flow equation in real and polar forms; Review of Newton's method for solution; Adjustment of P-V buses; Review of Fast Decoupled Power Flow method; Sensitivity factors for P-V bus adjustment.

UNIT III OPTIMAL POWER FLOW 9

Problem statement; Solution of Optimal Power Flow (OPF) – The gradient method, Newton's method, Linear Sensitivity Analysis; LP methods – With real power variables only – LP method with AC power flow variables and detailed cost functions Security constrained Optimal Power Flow; Interior point algorithm; Bus Incremental costs.

UNIT IV SHORT CIRCUIT ANALYSIS 9

Formation of bus impedance matrix with mutual coupling (single phase basis and three phase basis) - Computer method for fault analysis using ZBUS and sequence components. Derivation of equations for bus voltages, fault current and line currents, both in sequence and phase – symmetrical and unsymmetrical faults.

UNITV TRANSIENT STABILITY ANALYSIS 9

Introduction, Numerical Integration Methods: Euler and Fourth Order Runge-Kutta methods, Algorithm for simulation of SMIB and multi-machine system with classical synchronous machine model; Factors influencing transient stability, Numerical stability and implicit

Integration methods.

L:45 +T: 15 TOTAL:60 PERIODS

1. B.W Williams ‘Power Electronics Circuit Devices and Applications’..
2. A.J.Wood and B.F.Wollenberg, “Power Generation Operation and Control”, John Wiley and sons, New York, 1996.
3. W.F.Tinney and W.S.Meyer, “Solution of Large Sparse System by Ordered Triangular Factorization” IEEE Trans. on Automatic Control, Vol : AC-18, pp:333- 346, Aug 1973.
4. K.Zollenkopf, “Bi-Factorization: Basic Computational Algorithm and Programming Techniques; pp:75-96 ; Book on “Large Sparse Set of Linear Systems” Editor: J.K.Rerd, Academic Press, 1971.
5. M.A.Pai,” Computer Techniques in Power System Analysis”,Tata McGraw-Hill Publishing Company Limited, New Delhi, 2006.
6. G W Stagg , A.H El. Abiad, “Computer Methods in Power System Analysis”, McGraw Hill, 1968.
7. P.Kundur, “Power System Stability and Control”, McGraw Hill, 1994.

WEB RESOURCES:

- https://presentgroup.com.au/power-system-modelling-and-analysis/
- https://www.osti.gov/servlets/purl/1083672
- https://link.springer.com/chapter/10.1007/978-3-319-02393-9_2
- https://www.engineersaustralia.org.au/Event/power-system-modelling-and-analysis-presentation
- https://www.academia.edu/25013211/Modelling_and_Analysis_of_Electric_Power_Systems_Power_Flow_Analysis_Fault_Analysis_Power_Systems_Dynamics_and_Stability
- http://www.optimisedenergysolutions.com/services-modellingandanalysis.aspx

COURSE OUTCOMES:

CO No	**COURSE OUTCOMES**
CO103.1	Ability to apply the concepts of sparse matrix for large scale power

system analysis.

CO103.2	Ability to analyze power system studies that needed for the transmission system planning.
CO103.3	Able to solve optimal power flow problems.
CO103.4	Able to analyse short circuit faults and understand the consequence faults.
CO103.5	Ability to understand AI integration methods and factors influencing transient stability.

POs Vs COs MAPPING:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO103.1	3	2										
CO103.2	2	3	3			1						
CO103.3	1	2	3		3	2					2	
CO103.4		2	2		2	2					2	
CO103.5		2			2	2					2	

1 ❼ Low 2 ❼ Medium 3 ❼ High

19PS1603	**POWER SYSTEM OPERATION AND CONTROL**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

OBJECTIVES:

- To understand the fundamentals of speed governing system and the concept of control areas.
- To provide knowledge about Hydro thermal scheduling, Unit commitment and solution techniques.
- To impart knowledge on the need of state estimation and its role in the day- today operation of power system.

PRE-REQISITE:

- POWER SYSTEM ANALYSIS
- CONTROL SYSTEM
- POWER PLANT ENGINEERING

UNIT I INTRODUCTION 9

System load variation: System load characteristics, load curves - daily, weekly and annual, load-duration curve, load factor, diversity factor. Reserve requirements: Installed reserves, spinning reserves, cold reserves, hot reserves. Overview of system operation: Load forecasting, techniques of forecasting, basics of power system operation and control.

UNIT II REAL POWER- FREQUENCY CONTROL 9

Fundamentals of speed governing mechanism and modeling: Speed-load characteristics– Load sharing between two synchronous machines in parallel; concept of control area, LFC control of a single - area system: Static and dynamic analysis of uncontrolled and controlled cases, Economic Dispatch Control. Multi-area systems: Two-area system modeling; static analysis, uncontrolled case; tie line with frequency bias control of two-area system derivation.

UNIT III HYDRO THERMAL SCHEDULING PROBLEM 9

Hydrothermal scheduling problem: short term and long term-mathematical model, algorithm. Dynamic programming solution methodology for Hydro-thermal scheduling with pumped hydro plant: Optimization with pumped hydro plant – Scheduling of systems with pumped hydro plant during off-peak seasons: algorithm. Selection of initial feasible trajectory for pumped hydro plant– Pumped hydro plant as spinning reserve unit-generation of out age induced constraint.

UNIT IV UNIT COMMITMENT AND ECONOMIC DISPATCH 9

Statement of Unit Commitment (UC) problem; constraints in UC: spinning reserve, thermal unit constraints, hydro constraints, fuel constraints and other constraints; UC solution methods: Priority-list methods, forward dynamic programming approach, numerical problems. Incremental cost curve, co-ordination equations without loss and with loss, solution by direct method and λ-iteration method. Base point and participation factors- Economic dispatch controller added to LFC control.

UNIT V STATE ESTIMATION 9

Need for power system state estimation- Network observe ability– DC state estimation model- State estimation of power system–Methods of state estimation: Least square state estimation, Weighted least square state estimation, Maximum like hood- Bad data detection and identification.

TOTAL: 45 PERIODS

REFERENCE(S):

1. Olle. I. Elgerd, "Electric Energy Systems Theory – An Introduction", Tata McGraw Hill Publishing Company Ltd, New Delhi, Second Edition, 2003.
2. D.P. Kothari and I.J. Nagrath, "Modern Power System Analysis", Third Edition, Tata McGraw Hill Publishing Company Limited, New Delhi, 2003.
3. L.L. Grigsby, "The Electric Power Engineering, Hand Book", CRC Press & IEEE Press,2001.
4. Allen.J. Wood and Bruce F.Wollenberg, "Power Generation, Operation and Control", John Wiley & Sons, Inc., 2003.
5. P. Kundur, "Power System Stability & Control", McGraw Hill Publications, USA, 1994.

WEB SOURCE(S):

1. https://nptel.ac.in/courses/108/101/108101040/
2. http://www.crectirupati.com/sites/default/files/lecture_notes/PSOC%20-%20%20IV%20-%20EEE_0.pdf

COURSE OUTCOMES:

CO104.1	Learners will be able to understand system load variations and get an overview of power system operations.
CO104.2	Learners will be exposed to power system state estimation.
CO104.3	Learners will attain knowledge about hydrothermal scheduling.
CO104.4	Learners will understand the significance of unit commitment and different solution methods.
CO104.5	Learners will understand the need for state estimation in real time operation

POs Vs COs MAPPING:

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO104.1	2	2	2	1				2		
CO104.2	2	2	1	1				2		
CO104.3	2	2	1	1				2		
CO104.4	2	2	1	1				2		
CO104.5	2	2	1	1				2		

1 ❼ Low 2 ❼ Medium 3 ❼ High

19PE1605	SYSTEM THEORY	L	T	P	C
		3	1	0	4

COURSE OBJECTIVES:

- To understand the fundamentals of physical systems in terms of its linear and nonlinear models.
- To educate on representing systems in state variable form.
- To educate on solving linear and non-linear state equations.
- To exploit the properties of linear systems such as controllability and observability.
- To educate on stability analysis of systems using Lyapunov's theory.
- To educate on modal concepts and design of state and output feedback controllers and estimators.

PRE REQUISITE:

UG level Control system

UNIT I STATE VARIABLE REPRESENTATION 9

Introduction- Concept of State-State equations for Dynamic Systems - Time invariance and linearity- Non uniqueness of state model- Physical Systems and State Assignment - free and forced responses- State Diagrams.

UNIT II SOLUTION OF STATE EQUATIONS 9

Existence and uniqueness of solutions to Continuous-time state equations - Solution of Nonlinear and Linear Time Varying State equations - State transition matrix and its properties – Evaluation of matrix exponential- System modes- Role of Eigen values and Eigen vectors.

UNIT III STABILITY ANALYSIS OF LINEAR SYSTEMS 9

Controllability and Observe ability definitions and Kalman rank conditions –Stabilize ability and Detect ability-Test for Continuous time Systems- Time varying and Time invariant case- Output Controllability-Reducibility- System Realizations.

UNIT IV STATE FEEDBACK CONTROL AND STATE ESTIMATOR 9

Introduction- Controllable and Observable Companion Forms-SISO and MIMO Systems- The Effect of State Feedback on Controllability and Observe ability-Pole Placement by State Feedback for both SISO and MIMO Systems - Full Order and Reduced Order Observers.

UNIT V LYAPUNOV STABILTY ANALYSIS 9

Introduction-Equilibrium Points- BIBO Stability-Stability of LTI Systems- Stability in the sense of Lyapunov - Equilibrium Stability of Nonlinear Continuous-Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous-Time Autonomous Systems – Krasovskil's and Variable-Gradiant Method.

TOTAL : 45+15 = 60 PERIODS

REFERENCES:

1. M. Gopal, "Modern Control System Theory", New Age International, 2005.
2. K. Ogatta, "Modern Control Engineering", PHI, 2002.
3. John S. Bay, "Fundamentals of Linear State Space Systems", McGraw-Hill, 1999.
4. D. Roy Choudhury, "Modern Control Systems", New Age International, 2005.
5. John J. D'Azzo, C. H. Houpis and S. N. Sheldon, "Linear Control System Analysis and Design with MATLAB", Taylor Francis, 2003.
6. Z. Bubnicki, "Modern Control Theory", Springer, 2005.
7. C.T. Chen, "Linear Systems Theory and Design'' Oxford University Press, 3rd Edition,1999.
8. M. Vidyasagar, "Nonlinear Systems Analysis', 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey

WEB RESOURCES:

- **https://nptel.ac.in/courses/108106150/**

COURSE OUTCOMES:

CO105.1 Ability to represent the time-invariant systems in state space form as well as analyze, whether the system is stabilizable, controllable, observable and detectable.

CO105.2 Able to obtain the solutions to state equations.

CO105.3 Able to analyse the steady state stability of linear systems

CO105.4 Ability to design state feedback controller and state observers

CO105.5 Use the techniques such as describing function, Lyapunov Stability, Popov's Stability Criterion and Circle Criterion to assess the stability of certain class of non-linear system.

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO105.1	2	3	3	2					1	2
CO105.2	2	3	3	2					1	2
CO105.3	2	3	3	2					1	2
CO105.4	2	3	3	2					1	2
CO105.5	2	3	3	2					1	2

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PS1611 POWER SYSTEM SIMULATION LABORATORY

L	T	P	C
0	0	4	2

OBJECTIVE(S):

- To have hands on experience on various system studies and different techniques used for system planning using Software packages.
- To perform the dynamic analysis of power system.

PRE REQUISTE:

- Power System Analysis

LIST OF EXPERIMENTS

1. Power flow analysis by Newton-Raphson method and Fast decoupled method
2. Transient stability analysis of single machine-infinite bus system using classical machine model.
3. Contingency analysis: Generator shift factors and line outage distribution factors.
4. Economic dispatch using lamb da-iteration method.
5. Unit commitment: Priority-list schemes and dynamic programming.
6. State Estimation (DC)
7. Analysis of switching surge using EMTP: Energization of a long distributed- parameter line.
8. Analysis of switching surge using EMTP: Computation of transient recovery voltage.
9. Simulation and Implementation of Voltage Source Inverter.
10. Digital Over Current Relay Setting and Relay Coordination using Suitable software packages.
11. Co-ordination of over-current and distance relays for radial line protection.

COURSE OUTCOME(S):

Upon Completion of the course, the students will be able to:

CO107.1 Analyze the power flow using Newton-Raphson method.
CO107.2 Analyze the power flow Fast decoupled method
CO107.3 Perform contingency analysis & economic dispatch.
C0107.4 Set Digital Over Current Relay
C0107.5 Set Coordinate Relay

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO107.1	**1**			**1**						**2**
CO107.2	**1**		**2**	**2**						**2**
CO107.3	**2**			**2**						**3**
C0107.4	**2**			**3**						**3**
C0107.5	**3**			**3**						**2**

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PS2601 DIGITAL PROTECTION FOR POWER SYSTEM

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To illustrate concepts of transformer protection.
- To describe about the various schemes of Over current protection.
- To analyze distance and carrier protection.
- To familiarize the concepts of Generator protection and Numerical protection.

PRE REQUISTES

Power System Analysis

Power System Operation and Control

Protection and Switch Gear

UNIT I OVER CURRENT & EARTH FAULT PROTECTION 9

Zones of protection– Primary and Backup protection– operating principles and Relay Construction- Time– Current characteristics- Current setting– Time setting-Over current protective schemes–Concept of Coordination- Protection of parallel /ring feeders- Reverse power or directional relay –Polarization Techniques – Cross Polarization– Quadrature Connection – Earth fault and phase fault protection - Combined Earth fault and phase fault protection scheme- Phase fault protective-scheme directional earth fault relay –Static over current relays–Numerical over–current protection; numerical coordination example for a radial feeder.

UNIT II TRANSFORMER & BUSBAR PROTECTION 9

Types of transformers–Types of faults in transformers- Types of Differential Protection–High Impedance–External fault with one CT saturation–Actual behavior of protective CT–Circuit model of a saturated CT-Need for high impedance– Disadvantages –Percentage Differential Bias Characteristics–Vector group & its impact on differential protection-Inrush phenomenon–Zero Sequence filtering–High resistance Ground Faults in Transformers–Restricted Earth fault Protection-Inter-turn faults in transformers–Incipient faults in transformers- Phenomenon of over fluxing in transformers– Transformer protection application chart. Differential protection of busbars external and internal fault -Supervisory relay-protection of three–Phase busbars–Numerical example sound sign of high impedance busbar differential scheme–Biased Differential

Characteristics – Comparison between Transformer differential & Busbar differential.

UNIT III DISTANCE AND CARRIER PROTECTION OF TRANSMISSION LINES 9

Draw back of over–Current protection–Introduction to distance relay–Simple impedance relay– Reactance relay–mho relays comparison of distance relay–Distance protection of a three– Phase line- reasons for in accuracy of distance relay reach-Three stepped distance protection- Trip contact configuration for the three-Stepped distance protection-Three-stepped protection of three- phase line again install ten shunt faults-Impedance seen from relay side-Three-stepped protection of double end fed lines-need for carrier–Aided protection–Various options for a carrier– Coupling and trapping the carrier into the desired line section-Unit type carrier aided directional comparison relaying–Carrier aided distance schemes for acceleration of zone II; numerical example for a typical distance protection scheme for a transmission line.

UNIT IV GENERATOR PROTECTION 9

Electrical circuit of the generator–Various fault sand abnormal operating conditions–Stator Winding Faults–Protection against Stator(earth) faults – third harmonic voltage protection–Rotor fault – Abnormal operating conditions – Protection against Rotor faults–Potentiometer Method – injection method – Pole slipping– Loss of excitation– Protection against Mechanical faults; Numerical examples for typical generator protection schemes

UNIT V NUMERICAL PROTECTION 9

Introduction–Block diagram of numerical relay-Sampling theorem-Correlation with a reference wave–Least error squared(LES) technique -Digital filtering-numerical over-Current protection – Numerical transformer differential Protection - Numerical distance protection of transmission line.

TOTAL: 45 PERIODS

REFERENCES

1. Y.G.Paithankar and S.RBhide, "Fundamentals of Power System Protection", Prentice-Hall ofIndia,2003.
2. Badri Ram and D.N.Vishwakarma, "Power System Protection and Switch gear", Tata McGraw-Hill Publishing Company,2002.
3. T.S.M.Rao, "Digital Relay/Numerical relays", Tata McGraw Hill, New Delhi, 1989.
4. P.Kundur, "Power System Stability and Control", McGraw-Hill, 1993.

WEB RESOURCES

1. https://nptel.ac.in/courses/108101039/
2. http://www.cdeep.iitb.ac.in/webpage_data/nptel/Electrical%20Engineering/Power%20System%20Protection/TOC_M1.html

COURSE OUTCOMES:

CO201.1	Learners will be able to understand the various schemes available in Transformer protection.
CO201.2	Learners will have knowledge on Over current protection.
CO201.3	Learners will attain knowledge about Distance and Carrier protection in transmission lines
CO201.4	Learners will under stand the concepts of Generator protection.
CO201.5	Learners will attain basic knowledge on substation auto mation.

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO201.1	**2**									**3**
CO201.2	**2**									**3**
CO201.3	**2**									**3**
CO201.4	**2**									**3**
CO201.5	**2**		**3**					**3**		**3**

1 ❼ Low 2 ❼ Medium 3 ❼ High

		L	T	P	C
19PS2602	**POWER SYSTEM DYNAMICS AND STABILITY**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To impart knowledge on dynamic modeling of asynchronous machine in detail.
- To describe the modeling of excitation and speed governing system in detail.
- To understand the fundamental concepts of stability of dynamic systems and its

classification.

- To understand and enhance small signal stability problem of power systems.

PRE-REQISITE:

- Transmission and distribution
- Power system operation and control

UNITI SYNCHRONOUS MACHINE MODELLING 9

Schematic Diagram, Physical Description: armature and field structure, machines with multiple pole pairs, mmf wave forms, direct and quadrature axes, Mathematical Description of a Synchronous Machine: Basic equation sof asynchronous machine: stator circuit equations, stat or self, stat or mutual and stat or to rotormutualinductances,dq0Transformation: fluxlinkage and voltage equations for stat or and rotor in dq0 coordinates, electrical power and torque, physical interpretation of dq0 transformation, Per Unit Representations: power in variant form of Park "stransformation; Equivalent Circuits for direct and quadrature axes, Steady-state Analysis: Voltage, current andflux-link age relationships, Phas or representation, Rotorangle, Steady-state equivalent circuit, Computation of steady-statevalues, Equations of Motion: Swing Equation, calculation of inertia constant, Representation in system studies, Synchronous Machine Representation in Stability Studies: Simplifications for large-scale studies: Neglect of stator transients, Simplified model with amortisseurs neglected: two- axis model with amortisseur windings neglected, classical model.

UNITII MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS9

Excitation System Requirements; Elements of an Excitation System; Types of Excitation System; Control and protective functions; IEEE(1992) block diagram for simulation of excitation systems. Turbine and Governing System Modeling: Functional Block Diagram of Power Generation and Control, Schematic of a hydro electric plant, classical transfer function of a hydraulic turbine (noderivation), special characteristic of hydraulic turbine, electrical analogue of hydraulic turbine, Governor for Hydraulic Turbine: Requirement for a transient droop, Block diagram of governor with transient droop compensation, Steam turbine modeling: Single reheat tandem compounded type only and IEEE block diagram for dynamic simulation; generic speed- governing system model for normal speed/load control function.

UNIT III SMALL-SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS 9

Classification of Stability, Basic Concepts and Definitions: Rotor angle stability, The Stability Phenomena. Fundamental Concept sof Stability of Dynamic Systems: State-space representation, stability of dynamic system, Linearization, Eigen properties of the state matrix: Eigen values and eigen vectors, modal matrices, Eigen value and stability, mode shape and participation factor. Single-Machine Infinite Bus(SMIB) Configuration: Classical Machine Model stability analysis with numerical example, Effects of Field Circuit Dynamics: synchronous machine, network and line arised system equations, block diagram representation with K-constants; expression for K-constants (no derivation), effect of field flux variation on system stability: analysis with numerical example.

UNIT IV SMALL-SIGNAL STABILITY ANALYSIS WITH CONTROLLERS 9

Effects of Excitation System: Equations with definitions of appropriate K-constants and simple thyristor excitation system and AVR, block diagram with the excitation system, analysis of effect of AVR on synchronizing and damping components using a numerical example, Power System Stabilizer: Block diagram with AVR and PSS, Illustration of principle of PSS application with numerical example, Block diagram of PSS with description, system state matrix including PSS, analysis of stability with numerical a example. Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix for a two-machine system with classical models for synchronous machines, illustration of stability analysis using a numerical example. Principle behind small- signal stability improvement methods: delta-omega and delta P-omega stabilizers.

UNITV ENHANCEMENT OF SMALL SIGNAL STABILITY 9

Power System Stabilizer – Stabilizer based on shaft speed signal (delta omega)–Delta–P-Omega stabilizer – Frequency- based stabilizers– Digital Stabilizer–Excitation control design–Exciter gain–Phase lead compensation–Stabilizing signal wash out stabilizer gain–Stabilizer limits

TOTAL: 45 PERIODS

TEXT BOOKS:

1. Mohan Mathur, R., Rajiv. K. Varma, “Thyristor – Based Facts Controllers for Electrical

Transmission Systems”, IEEE press and John Wiley & Sons, Inc.

2. P. W. Sauer and M. A. Pai, “Power System Dynamics and Stability”, Stipes Publishing Co, 2007.
3. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 1993.
4. P.M Anderson and A.A Fouad, “Power System Control and Stability”, Iowa State University Press, Ames, Iowa, 1978.
5. R.Ramunujam, “Power System Dynamics Analysis and Simulation”, PHI Learning Private Limited, New Delhi, 2009.

WEB SOURCE(S):

- https://www.researchgate.net/publication/41231911_Power_System_Dynamics_ Stability and Control

COURSE OUTCOMES:

CO202.1 Learners will be able to understand on dynamic modeling of synchronous machine.

CO202.2 Learners will be able to understand the modeling of excitation and speed governing system for stability analysis.

CO202.3 Learners will attain knowledge about stability of dynamic systems.

CO202.4 Learners will understand the significance about small signal stability analysis with controllers.

CO202.5 Learners will understand the enhancement of small signal stability.

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO202.1	**2**	**1**	**1**	**1**				**2**		
CO202.2	**2**	**1**	**1**	**1**				**2**		
CO202.3	**2**	**1**	**1**	**1**				**2**		
CO202.4	**2**	**1**	**1**	**1**				**2**		
CO02.5	**2**	**1**	**1**	**1**				**2**		

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PS2603 **RESTRUCTURED POWER SYSTEM**

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To introduce the restructuring of power industry and market models.
- To impart knowledge on fundamental concepts of congestion management.
- To analyze the concepts of location al marginal pricing and financial transmission rights.
- To Illustrate about various power sectors in India.

PRE REQUISITE

- Power System
- Protection and Switchgear

UNIT I INTRODUCTION TO RESTRUCTURING OF POWER INDUSTRY 9

Introduction: Deregulation of power industry, restructuring process, Issues involved in deregulation, Deregulation of various power systems – Fundamentals of Economics: Consumer behavior, Supplier behavior, Market equilibrium, Short and long run costs, Various cost sof production– Market models: Market models based on Contractual arrangements, Comparison of various market models, Electricity vis–a–vis other commodities, Market architecture, Case study.

UNIT II TRANSMISSION CONGESTION MANAGEMENT 9

Introduction: Definition of Congestion, reasons for transfer capability limitation, Importance of congestion management, feature sof congestion management–Classification of congestion management methods– Calculation of ATC-Non–market methods– Market methods– Nodal pricing–Inter zonal and Intra zonal congestion management–Price are a congestion management– Capacity alleviation method.

UNIT III LOCATIONAL MARGINAL PRICES AND FINANCIAL TRANSMISSION RIGHTS 9

Mathematical preliminaries:- Locational marginal pricing–Loss less DCOPF model for LMP calculation–Loss compensated DCOPF model for LMP calculation–ACOPF model for LMP calculation–Financial Transmission rights– Risk hedging functionality -Simultaneous feasibility test and revenue a dequency – FTR issuance process: FTR auction, FTR allocation –Treatment of revenue short fall–Secondary trading of FTRs–Flow gate rights–FTR and market power –FTR and merchant transmission investment.

UNIT IV ANCILLARY SERVICE MANAGEMENT AND PRICING OF TRANSMISSION NETWORK 9

Introduction of ancillary services – Type sof Ancillary services–Classification of Ancillary services – Load generation balancing related services –Voltage control and reactive power support devices – Black start capability service - How to obtain ancillary service – Co-optimization of energy and reserve services - Transmission pricing – Principles – Classification – Rolled in transmission pricing methods – Marginal transmission pricing paradigm – Composite pricing paradigm–Merits and demerit sof different paradigm.

UNIT V REFORMS IN INDIAN POWER SECTOR 9

Introduction – Frame work of Indian power sector – Reform initiatives – Availability based tariff – Electricity act 2003 – Open access issues – Power exchange–Reforms in the near future.

TOTAL: 45 PERIODS

REFERENCES:

1. Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker, "Restructured electrical power systems: operation, tradingandvolatility"Pub.,2001.
2. Kankar Bhattacharya, Jaap E.Daadler, MathH.J. Boolen, "Operation of restructured power systems", Kluwer Academic Pub., 2001.
3. Paranjothi,S.R., **"**Modern Power Systems**"** Paranjothi, S.R.**,**NewAgeInternational,2017.

4. Sally Hunt," Making competition work in electricity", John Willey and Sons Inc.2002.
5. Steven Stoft, "Power system economics: designing markets for electricity", John Wiley & Sons, 2002.

WEB RESOURCES:

1. https://nptel.ac.in/courses/108101005/
2. https://nptel.ac.in/content/storage2/courses/108101040/download/Lec-33.pdf
3. https://www.coursebuffet.com/course/829/nptel/restructured-power-systems-iit-bombay

COURSE OUTCOMES:

CO203.1	Learners will have knowledge on restructuring of power industry
CO203.2	Learners will understand basics of congestion management
CO203.3	Learners will attain knowledge about locational margin prices and financial transmission rights
CO203.4	Learners will understand the significance ancillary services and pricing of transmission network
CO203.5	Learners will have knowledge on the various power sectors in India.

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
1	3					2				2
2	3					2				2
3	3		2			2				2
4	3					2				2
5	3					2				2

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PE2705 FLEXIBLE AC TRANSMISSION SYSTEMS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To emphasis the need for FACTS controllers.
- To learn the characteristics, applications and modelling of series and shunt FACTS controllers.
- To analyze the interaction of different FACTS controller and perform control coordination.

PRE-REQISITE:

- High Voltage Direct Current Engineering
- High Voltage Engineering

UNIT I INTRODUCTION 9

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

UNIT II STATIC VAR COMPENSATOR (SVC) 9

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

UNIT III THYRISTOR AND GTO THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC and GCSC) 9

Concepts of Controlled Series Compensation – Operation of TCSC and GCSC- Analysis ofTCSC - GCSC – Modelling of TCSC and GCSC for load flow studies - modelling TCSC and GCSC for stability studied- Applications of TCSC and GCSC.

UNIT IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9

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

UNIT V CONTROLLERS AND THEIR COORDINATION 9

FACTS Controller interactions – SVC–SVC interaction - co-ordination of multiple controllers using linear control techniques – Quantitative treatment of control coordination.

TOTAL : 45 PERIODS

REFERENCES:

1. A.T.John, "Flexible AC Transmission System", Institution of Electrical and Electronic Engineers (IEEE), 1999.
2. NarainG.Hingorani, Laszio. Gyugyl, "Understanding FACTS Concepts and Technology of Flexible AC Transmission System", Standard Publishers, Delhi 2001.
3. V. K.Sood, "HVDC and FACTS controllers- Applications of Static Converters in Power System", 2004, Kluwer Academic Publishers.
4. Mohan Mathur, R., Rajiv. K. Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons, Inc.
5. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International(P) Ltd., Publishers New Delhi, Reprint 2008.

WEB SOURCES:

- https://www.electrical4u.com/facts-on-facts-theory-and-applications/
- https://www.gegridsolutions.com/facts.htm

COURSE OUTCOMES:

CO204.1	Ability to understand the operation of the ac transmission lines and various types of FACTS
CO204.2	Ability to understand the basic concepts of VAR compensators
CO204.3	Ability to know about the modeling and applications of thyistors and GTO
CO204.4	Ability to understand the basic concepts voltage source convertor based FACTS

CO204.5 Ability to analysis the various Controllers and their Coordination

POs Vs COs Mapping:

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO204.1	2	2	1	2				2		
CO204.2	2	2	1	2				2		
CO204.3	2	2	1	2				2		
CO204.4	2	2	1	2				2		
CO204.5	2	2	1	2				2		

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PS2611	ADVANCED POWER SYSTEMSIMULATION LABORATORY	L	T	P	C
		0	0	4	2

OBJECTIVES

- To Introduce the infinite bus system for single and classical machines.
- To impart knowledge on starting characteristics of AC machines using hands on training.
- To compute the two-bus system with STATCOM
- To design the variable speed wind energy conversion system
- To design the various active filters for improving the power quality

PRE-REQUISITE:

- Power system Analysis
- Power System operation control
- Power Quality

LISTOFEXPERIMENTS

1. Small-signal stability analysis of single machine-infinite bus system using classical machine model
2. Small-signal stability analysis of multi-machine configuration with classical machine model

3. Induction motor starting analysis.
4. Load flow analysis of two-bus system with STATCOM.
5. Transient analysis of two-bus system with STATCOM.
6. Available Transfer Capability calculation using an existing load flow program.
7. Study of variable speed wind energy conversion system- DFIG.
8. Study of variable speed wind energy conversion system- PMSG.
9. Computation of harmonic indices generated by a rectifier feeding a R-L load.
10. Design of active filter for mitigating harmonics.

TOTAL:30 PERIODS

WEB SOURCE(S):

- https://nptel.ac.in/courses/108105067/

COURSE OUTCOMES(S):

Upon Completion of the course, the students will be able to:

CO207.1	Ability to analysis of single machine-infinite bus system using classical machine model
CO207.2	Ability to analysis of starting of AC Machine
CO207.3	Ability to analysis of two-bus system with STATCOM
CO207.4	Understand the concept of variable speed wind energy conversion system
CO207.5	Ability to design the active filter for filtering harmonics

PO vs CO Mapping

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO207.1	3	2	2			2		2		2
CO207.2	3	2	2			2		2		2
CO207.3	3	2	2	1		2		2		2
CO207.4	3	2	2	1		2		2		2
CO207.5	3	2	2	2		2		2		2

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PE1603	MODELLING AND ANALYSIS OF ELECTRICAL MACHINES	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To provide knowledge about the fundamentals of magnetic circuits, energy, force and torque of multi-excited systems.
- To analyze the steady state and dynamic state operation of DC machine through mathematical modeling and simulation in digital computer.
- To provide the knowledge of theory of transformation of three phase variables to two phase variables.
- To analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modeling and digital computer simulation.
- To analyze the steady state and dynamic state operation of three-phase synchronous machines using transformation theory based mathematical modeling and digital computer simulation.

PRE-REQUISITE:

- Electrical Machines

UNIT I PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9

Magnetic circuits, permanent magnet, stored magnetic energy, co-energy - force and torque in singly and doubly excited systems – machine windings and air gap mmf - winding inductances and voltage equations.

UNIT II DC MACHINES 9

Elementary DC machine and analysis of steady state operation - Voltage and torque equations – dynamic characteristics of permanent magnet and shunt d.c. motors – Time domain block diagrams - solution of dynamic characteristic by Laplace transformation – digital computer simulation of permanent magnet and shunt D.C. machines.

UNIT III REFERENCE FRAME THEORY 9

Historical background – phase transformation and commutator transformation – transformation of variables from stationary to arbitrary reference frame - variables observed from several frames of reference.

UNIT IV INDUCTION MACHINES 9

Three phase induction machine, equivalent circuit and analysis of steady state operation – free acceleration characteristics – voltage and torque equations in machine variables and arbitrary reference frame variables – analysis of dynamic performance for load torque variations – digital computer simulation.

UNIT V SYNCHRONOUS MACHINES 9

Three phase synchronous machine and analysis of steady state operation - voltage and torque equations in machine variables and rotor reference frame variables (Park's equations) –analysis of dynamic performance for load torque variations – Generalized theory of rotating electrical machine.

TOTAL: 45 PERIODS

REFERENCE BOOKS:

1. Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition, 2010.
2. P S Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers, 2008.
3. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, "Electric Machinery", Tata McGraw Hill, 5th Edition, 1992.
4. R. Krishnan, Electric Motor & Drives: Modeling, Analysis and Control, New Delhi, Prentice Hall of India, 2001.

WEB SOURCES:

1. https://nptel.ac.in/content/syllabus_pdf/108106023.pdf
2. https://nptel.ac.in/courses/108106023/

COURSE OUTCOMES:

CO106-1.1 Ability to understand the various electrical parameters in mathematical form

CO106-1.2 Ability to understand the different types of reference frame theories and transformation relationships.

CO106-1.3 Ability to find the electrical machine equivalent circuit parameters and modeling of electrical machines.

CO106-1.4 Ability to know about the equivalent circuit parameters and modeling of Induction machines

CO106-1.5 Ability to know about the equivalent circuit parameters and modeling of Synchronous machines

PO vs CO Mapping

CO No	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO106-1.1	**2**	**1**	**2**					**2**		
CO106-1.2	**2**	**1**	**2**					**2**		
CO106-1.3	**2**	**1**	**2**					**2**		
CO106-1.4	**2**	**1**	**2**					**2**		
CO106-1.5	**2**	**1**	**2**					**2**		

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PE1604 SOLAR AND ENERGY STORAGE SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To Study about solar modules and PV system design and their applications
- To Deal with grid connected PV systems
- To Discuss about different energy storage systems

PRE-REQISITE:

Power Electronics for Renewable Energy Systems

UNIT I INTRODUCTION **9**

Characteristics of sunlight – semiconductors and P-N junctions –behavior of solar cells – cell properties – PV cell interconnection

UNIT II STAND ALONE PV SYSTEM **9**

Solar modules – storage systems – power conditioning and regulation - MPPT- protection –stand alone PV systems design – sizing

UNIT III GRID CONNECTED PV SYSTEMS **9**

PV systems in buildings – design issues for central power stations – safety – Economic aspect – Efficiency and performance - International PV programs

UNIT IV ENERGY STORAGE SYSTEMS **9**

Impact of intermittent generation – Battery energy storage – solar thermal energy storage – pumped hydroelectric energy storage

UNIT V APPLICATIONS **9**

Water pumping – battery chargers – solar car – direct-drive applications –Space – Telecommunications.

TOTAL : 45 PERIODS

REFERENCES

1. Solanki C.S., "Solar Photovoltaics: Fundamentals, Technologies And Applications", PHI Learning Pvt. Ltd., 2015.
2. Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, "AppliedPhotovoltaics", 2007,Earth scan, UK.

3. Eduardo Lorenzo G. Araujo, “Solar electricity engineering of photovoltaic systems”, Progensa,1994.
4. Frank S. Barnes & Jonah G. Levine, “Large Energy storage Systems Handbook”, CRC Press, 2011.
5. McNeils, Frenkel, Desai, “Solar & Wind Energy Technologies”, Wiley Eastern, 1990 S.P. Sukhatme , “Solar Energy”, Tata McGraw Hill,1987.

WEB SOURCE(S):

1. https://nptel.ac.in/courses/112105051/
2. https://www.nationalgeographic.com/environment/energy/reference/renewable-energy/

COURSE OUTCOME(S):

CO106-2.1	Students will develop more understanding on solar energy storage systems
CO106-2.2	Students will develop basic knowledge on standalone PV system
CO106-2.3	Students will understand the issues in grid connected PV systems
CO106-2.4	Students will study about the modeling of different energy storage systems and their performances
CO106-2.5	Students will attain more on different applications of solar energy

POs Vs COs Mapping:

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO106-2.1	**3**	**1**	**1**			**2**	**2**		**1**	
CO106-2.2	**3**	**1**	**1**			**2**	**2**		**1**	
CO106-2.3	**3**	**1**	**1**			**2**	**2**		**1**	
CO106-2.4	**3**	**1**	**1**			**2**	**2**		**1**	
CO106-2.5	**3**	**1**	**1**			**2**	**2**		**1**	

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PE2704	SOFT COMPUTING TECHNIQUES	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To expose the concepts of feed forward neural networks.
- To provide adequate knowledge about feedback neural networks.
- To teach about the concept of fuzziness involved in various systems.
- To expose the ideas about genetic algorithm
- To provide adequate knowledge about of FLC and NN toolbox

PRE-REQUISITE:

- Engineering Physics

UNIT I INTRODUCTION AND ARTIFICIAL NEURAL NETWORKS 9

Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Properties of Swarm Intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems -Neuron- Nerve structure and synapse - Artificial Neuron and its model- activation functions- Neural network architecture- single layer and multilayer feed forward networks- Mc Culloch Pitts neuron model- perceptron model- Adaline and Madaline- multilayer perception model- back propagation learning methods- effect of learning rule coefficient -back propagation algorithm- factors affecting back propagation training- applications.

UNIT II ARTIFICIAL NEURAL NETWORKS AND ASSOCIATIVE MEMORY 9

Counter propagation network- architecture- functioning & characteristics of counter Propagation network- Hopfield/ Recurrent network configuration - stability constraints associative memory and characteristics- limitations and applications- Hopfield v/s Boltzman machine- Adaptive

Resonance Theory- Architecture- classifications- Implementation and training - Associative Memory.

UNIT III FUZZY LOGIC SYSTEM 9

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

UNIT IV GENETIC ALGORITHM 9

Evolutionary programs – Genetic algorithms, genetic programming and evolutionary programming - Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators - Optimization problems using GA-discrete and continuous - Single objective and multi-objective problems - Procedures in evolutionary programming.

UNIT V HYBRID CONTROL SCHEMES 9

Fuzzification and rule base using ANN – Neuro fuzzy systems - ANFIS – Fuzzy Neuron - Optimization of membership function and rule base using Genetic Algorithm – Introduction to Support Vector Machine- Evolutionary Programming-Particle Swarm Optimization - Case study – Familiarization of NN, FLC and ANFIS Tool Box.

TOTAL: 45 PERIODS

TEXT BOOKS:

1. Laurene V. Fausett, “Fundamentals of Neural Networks: Architectures, Algorithms And Applications”, Pearson Education.
2. Timothy J. Ross, “Fuzzy Logic with Engineering Applications” Wiley India, 2008.
3. Zimmermann H.J. "Fuzzy set theory and its Applications" Springer international edition, 2011.
4. David E.Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Pearson Education, 2009.
5. W.T.Miller, R.S.Sutton and P.J.Webrose, “Neural Networks for Control” MIT Press”, 1996.
6. T. Ross, “Fuzzy Logic with Engineering Applications”, Tata McGraw Hill, New Delhi, 1995.

7. Ethem Alpaydin, “Introduction to Machine Learning (Adaptive Computation and Machine Learning Series)”, MIT Press, 2004.
8. Corinna Cortes and V. Vapnik, " Support - Vector Networks, Machine Learning ” 1995.

WEB SOURCES:

3. https://nptel.ac.in/courses/106/105/106105173/
4. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/106105173/lec1.pdf

COURSE OUTCOMES:

CO106-3.1 Will be able to know the basic ANN architectures, algorithms and their limitations.

CO106-3.2 Will be able to know the different operations on the fuzzy sets.

CO106-3.3 Will be capable of developing ANN based models and control schemes for non-linear system.

CO106-3.4 Will get expertise in the use of different ANN structures and online training algorithm.

CO106-3.5 Will be knowledgeable to use Fuzzy logic for modeling and control of non-linear systems.

PO vs CO Mapping

CO No	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO106-3.1	**1**	**2**			**2**			**1**		
CO106-3.2	**1**	**2**			**2**			**1**		
CO106-3.3	**1**	**2**			**2**			**1**		
CO106-3.4	**1**	**2**			**2**			**1**		
CO106-3.5	**1**	**2**			**2**			**1**		

1 ❼ Low 2 ❼ Medium 3 ❼ High

19PE3707 **SMART GRID**

L	T	P	C
3	0	0	3

OBJECTIVES:

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

PRE -REQUISITE:

- Transmission & Distribution
- Power System Analysis

UNIT I INTRODUCTION TO SMART GRID 9

Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, National and International Initiatives in Smart Grid.

UNIT II SMART GRID TECHNOLOGIES 9

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).

UNIT III SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9

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.

UNIT IV POWER QUALITY MANAGEMENT IN SMART GRID 9

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.

UNIT V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

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.

TOTAL : 45 PERIODS

REFERENCES:

1. Stuart Borlase “Smart Grid: Infrastructure, Technology and Solutions”, CRC Press 2012.
2. Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley 2012.
3. Vehbi C. Güngör, Dilan Sahin, Task in Kocak, 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.
4. Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang “Smart Grid – The New and Improved Power Grid: A Survey” , IEEE Transaction on Smart Grids, vol. 14, 2012.

WEB RESOURCES:

1. https://nptel.ac.in/courses/108/107/108107113/
2. http://www.digimat.in/nptel/courses/video/108107113/108107113.html
3. http://www.digimat.in/nptel/courses/video/108107113/108107113.html

COURSE OUTCOMES:

CO205-1.1	Learners will develop more understanding on the concepts of Smart Grid and its present developments.
CO205-1.2	Learners will study about different Smart Grid technologies.
CO205-1.3	Learners will acquire knowledge about different smart meters and advanced metering infrastructure.
CO205-1.4	Learners will have knowledge on power quality management in Smart Grids.
CO205-1.5	Learners will develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

POs Vs COs Mapping:

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO205-1.1	3		3			2			2	2
CO205-1.2	3		3			2			2	2
CO205-1.3	3		3			2			2	2
CO205-1.4	3		3			2			2	2
CO205-1.5	3		3			2			2	2

19PE1602	ANALYSIS AND DESIGN OF POWER CONVERTERS AND INVERTERS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To determine the operation and characteristics of Power converters.
- To introduce the design of power converter components.
- To comprehend the concepts of resonant converters and AC-AC power converters.
- To analyze and comprehend the various types of inverters.

- To impart knowledge on multilevel inverters and Boost inverters.

PRE-REQUISITE:

- Power Electronics
- Solid State Drives
- Power Electronics For Renewable Energy Sources.

UNIT I POWER CONVERTERS 9

Single - phase and Three phase full converter and semi converter (RL, RLE load) - Dual converter – PWM rectifiers. Operation and analysis of Buck, Boost, Buck - Boost, Cuk & SEPIC – under continuous and discontinuous operation – Isolated converters: basic operation of Fly back, Forward and Push-pull topologies.

UNIT II DESIGN OF POWER CONVERTER COMPONENTS 9

Introduction to magnetic materials- hard and soft magnetic materials – types of cores , copper windings – Design of transformer –Inductor design equations –Examples of inductor design for buck/fly back converter-selection of output filter capacitors – selection of ratings for devices – input filter design.

UNIT III RESONANT DC-DC CONVERTERS& AC-AC CONVERTERS9

Resonant switch converters – operation and analysis of ZVS, ZCS converters comparison of ZCS/ZVS Introduction to ZVT/ZCT PWM converters. Single phase ac voltage controller – analysis with R & RL load – Three phase ac voltage controller – principle of operation of cyclo converter – single phase and three phase cyclo converters – Introduction to matrix converters.

UNIT IV VOLTAGE SOURCE AND CURRENT SOURCE INVERTERS 9

Principle of operation of single phase full bridge inverters, Three phase Inverter: 180 degree and 120 degree conduction mode inverters – voltage control of inverters : Space vector modulation techniques .Operation of six-step thyristor inverter load – commutated inverters – Auto sequential current source inverter (ASCI), PWM techniques forcurrent source inverters.

UNIT V MULTILEVEL INVERTERS , BOOST & RESONANT INVERTERS 9

Multilevel concept – diode clamped – flying capacitor – cascade type multilevel inverters - Comparison of multilevel inverters .Series and parallel resonant inverters - voltage control of resonant inverters – Class Eresonant inverter – resonant DC - link inverters

TOTAL : 45 PERIODS

TEXT BOOKS:

1. Ned Mohan, T.MUndeland and W.P Robbin, "Power Electronics: converters, Application and design" John Wiley and sons. Wiley India edition, 2006.
2. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Prentice Hall India, Third Edition, New Delhi, 2004.
3. P.C. Sen, "Modern Power Electronics", Wheeler Publishing Co, First Edition, New Delhi, 1998.
4. P.S.Bimbra, "Power Electronics", Khanna Publishers, Eleventh Edition, 2003.
5. Simon Ang, Alejandro Oliva, "Power-Switching Converters, Second Edition, CRC Press, Taylor & Francis Group, 2010.
6. V.Ramanarayanan, "Course material on Switched mode power conversion", 2007.

REFERENCES:

1. Alex Van den Bossche and Vencislav Cekov Valchev, "Inductors and Transformers for Power Electronics", CRC Press, Taylor & Francis Group, 2005.
2. W. G. Hurley and W. H.Wolfle, "Transformers and Inductors for Power Electronics Theory, Design and Applications", 2013 John Wiley & Sons Ltd.
3. Marian.K.Kazimierczuk and Dariusz Czarkowski, "Resonant Power Converters", John Wiley & Sons limited, 2011.
4. Jai P.Agrawal, "Power Electronics Systems", Pearson Education, Second Edition, 2002

5. Bimal K.Bose “Modern Power Electronics and AC Drives”, Pearson Education, Second Edition, 2003.
6. Philip T. krein, “Elements of Power Electronics” Oxford University Press -1998.

WEB RESOURCES:

1. https://www.powerelectronics.com/technologies/dc-dc-converters/article/21861281/buckconverter-design-demystified
2. https://www.youtube.com/watch?v=LwPJi3jyfw0
3. http://dese.iisc.ac.in/design-of-power-converters/

COURSE OUTCOMES:

CO205-2.1	Analyze various power converters
CO205-2.2	Develop improved power converters for any stringent application requirements.
CO205-2.3	Design resonant and ac-ac converters.
CO205-2.4	Develop various types of inverter.
CO205-2.5	Design Multilevel Inverters and boot inverters.

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO205-2.1	3	3								3
CO205-2.2	3		2							3
CO205-2.3	3		2							3
CO205-2.4	3		2							3
CO205-2.5	3		2							3

19PS2701 POWER SYSTEM RELIABILITY

L	T	P	C
3	0	0	3

OBJECTIVES:

- To introduces the objective sof Load forecasting.
- To study the fundamental sof Generation system, transmission system and Distribution system reliability analysis
- To understand the Contingency analysis and Probabilistic Load flow Analysis.
- To illustrate the basic concept sof Expansion planning.
- To gain knowledge on the fundamental concept sof the Distribution system planning.

PRE-REQISITE:

- Transmission and Distribution
- Power System Analysis
- Protection and Switchgear
- Power Quality

UNIT I LOAD FORECASTING 9

Objectives of forecasting – Load growth patterns and their importance in planning - Load forecasting Based on discounted multiple regression technique – Weather sensitive load forecasting – Determination of annual forecasting – Use of AIin load forecasting.

UNIT II GENERATION SYSTEMRELIABILITYANALYSIS 9

Probabilistic generation and load models – Determination of LOLP and expected value of demand not served – Determination of reliability of ISO and interconnected generation systems.

UNIT III TRANSMISSION SYSTEM RELIABILITY ANALYSIS 9

Deterministic contingency analysis – probabilistic load flow-Fuzzy load flow probabilistic transmission system reliability analysis – Determination of reliability in dices like LOLP and expected value of demand not served.

UNIT IV EXPANSION PLANNING 9

Basic concepts on expansion planning – procedure followed for integrate transmission system planning, current practice in India – Capacitor place rproblemin transmission system and radial distributions system.

UNITV DISTRIBUTION SYSTEMPLANNING OVERVIEW 9

Introduction, sub transmission lines and distribution substations-Design primary and secondary systems – distribution system protection and coordination of protective devices.

TOTAL: 45 PERIODS

REFERENCES

1. Frank S. Barnes & Jonah G. Levine, "Large Energy storage Systems Handbook", CRC Press, 2011.
2. McNeils, Frenkel, Desai, "Solar & Wind Energy Technologies", Wiley Eastern, 1990
3. S.P. Sukhatme , "Solar Energy", Tata McGraw Hill,1987.
4. Roy Billinton & Ronald N.Allan, "Reliability Evaluation of Power Systems" Springer Publication,
5. R.L.Sullivan, "Power System Planning", Tata Mc Graw Hill Publishing Company Ltd 1977.
6. X.Wang&J.R. McDonald, "Modern Power System Planning", Mc Graw Hill Book Company1994.
7. T. Gonen, "Electrical Power Distribution Engineering", McGraw Hill Book Company 1986.
8. B.R. Gupta, "Generation of Electrical Energy",S.ChandPublications1983.

WEB RESOURCES:

- https://www.intechopen.com/books/system-reliability/power-system-reliability-mathematical-models-and-applications
- https://www.sciencedirect.com/science/article/abs/pii/095183209090007A
- https://link.springer.com/chapter/10.1007/978-1-84996-232-2_8
- https://www.researchgate.net/publication/278683001_Electric_Power_System_Reliability
- https://www.energy.gov/sites/prod/files/2017/01/f34/Maintaining%20Reliability%20in%20the%20Modern%20Power%20System.pdf

COURSE OUTCOMES:

CO205-3.1	Students will develop the ability to learn about load forecasting.
CO205-3.2	Students will learn about reliability analysis of ISO and inter connected systems.
CO205-3.3	Students will understand the concepts of Contingency analysis and Probabilistic Load flow Analysis.
CO205-3.4	Students will be able to understand the concepts of Expansion planning
CO205-3.5	Students will have knowledge on the fundamental concepts of the Distribution system planning.

POs Vs COs MAPPING:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO205-3.1	3	3						3		
CO205-3.2	3									
CO205-3.3	2	2	3		2					
CO205-3.4	2				2					
CO205-3.5	3							3		

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PE3701 HIGH VOLTAGE DIRECT CURRENTTRANSMISSION

L	T	P	C
3	0	0	3

OBJECTIVES:

- To impart knowledge on DC Power Transmission Technology
- To impart knowledge on operation, modelling and control of HVDC link.
- To impart knowledge on Multiter minal system

- To perform steady state analysis of AC/DC system.
- To expose various HVDC simulators.

PRE-REQISITE:

- Power Electronics
- Power Generation Systems
- Power systems Analysis
- Power system operation and control

UNIT I DC POWER TRANSMISSION TECHNOLOGY 9

Introduction - Comparison of AC and DC transmission – Application of DC transmission – Description of DC transmission system - Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables, VSC based HVDC.

UNIT II THYRISTOR BASED HVDC CONVERTERS AND HVDC SYSTEM CONTROL 9

Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters. General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering - power control – Higher level controllers-Valve tests.

UNIT III MULTITERMINAL DC SYSTEMS 9

Introduction – Potential applications of MTDC systems - Types of MTDC systems – Control and protection of MTDC systems - Study of MTDC systems.

UNIT IV POWER FLOW ANALYSIS IN AC/DC SYSTEMS 9

Per unit system for DC Quantities - Modeling of DC links - Solution of DC load flow - Solution of AC-DC power flow – Unified, Sequential and Substitution of power injection method

UNIT V SIMULATION OF HVDC SYSTEMS 9

Introduction – DC LINK Modelling, Converter Modeling and State Space Analysis, Philosophy and tools – HVDC system simulation, Online and OFF line simulators — Dynamic interactions between DC and AC systems.

TOTAL: 45 PERIODS

REFERENCES

1. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 1993
2. K.R.Padiyar, , “HVDC Power Transmission Systems”, New Age International (P) Ltd., New Delhi, 2002
3. J.Arrillaga, , “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 1983
4. rich Uhlmann, “ Power Transmission by Direct Current”, BS Publications, 2004.
5. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers

WEB SOURCE(S):

- https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/108104013/lec1.pdf
- https://www.cet.edu.in/noticefiles/229_HVDC_NOTE.pdf
- https://nptel.ac.in/content/syllabus_pdf/108104013.pdf

COURSE OUTCOME(S):

The students will able to

CO206-1.1	Understand knowledge on operation, modeling and control of HVDC link
CO206-1.2	Understand knowledge on thyristor based HVDC converters
CO206-1.3	Understand knowledge on multi terminal DC systems
CO206-1.4	Understand knowledge on power flow analysis in AC/DC systems
CO206-1.5	Expose various HVDC simulators.

PO vs CO Mapping:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO206-1.1	2									3
CO206-1.2	2									3
CO206-1.3	2									3

CO206-1.4	2									3
CO206-1.5	2		2		2			2		3

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PE2709 DISTRIBUTED GENERATION AND MICROGRID **L T P C**

3 0 0 3

OBJECTIVES:

- To illustrate the concept of distributed generation
- To impart knowledge on Distributed Generation
- To analyse the impact of grid integration.
- To study concept of Micro grid and its configuration
- To impart knowledge on Microgrid

PRE-REQISITE:

- Power Electronics
- Power Generation Systems
- Solid state drives
- Power system operation and control

UNIT I INTRODUCTION 9

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

UNIT II DISTRIBUTED GENERATIONS (DG) 9

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

UNIT III IMPACT OF GRID INTEGRATION 9

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

UNIT IV BASICS OF A MICROGRID 9

Concept and definition of micro grid, micro grid drivers and benefits, review of sources of micro grids, typical structure and configuration of a micro grid, AC and DC micro grids, Power Electronics interfaces in DC and AC micro grids.

UNIT V CONTROL AND OPERATION OF MICROGRID 9

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

TOTAL: 45 PERIODS

REFERENCES:

1. Amirnaser Yezdani, and Reza Iravani, "Voltage Source Converters in Power Systems: Modeling, Control and Applications", IEEE John Wiley Publications, 2010.
2. DorinNeacsu, "Power Switching Converters: Medium and High Power", CRC Press, Taylor& Francis, 2006.
3. Chetan Singh Solanki, "Solar Photo Voltaics", PHI learning Pvt. Ltd., New Delhi,2009.
4. J.F. Manwell, J.G. McGowan "Wind Energy Explained, theory design and applications", Wiley publication 2010.
5. D. D. Hall and R. P. Grover, "Biomass Regenerable Energy", John Wiley, New York, 1987.
6. John Twidell and Tony Weir, "Renewable Energy Resources" Tyalor and Francis Publications, Second edition 2006.

WEB SOURCE(S):

- https://nptel.ac.in/courses/108107143/
- https://nptel.ac.in/courses/108/108/108108034/
- https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/108107143/lec2.pdf

COURSE OUTCOME(S):

CO206-2.1	Learners will attain knowledge on the various schemes of conventional and non conventional power generation.
CO206-2.2	Learners will have knowledge on the topologies and energy sources of distributed generation.
CO206-2.3	Learners will learn about the requirements for grid interconnection and its impact with NCE sources
CO206-2.4	Learners will understand the fundamental concept of Micro grid.
CO206-2.5	Learners will understand the control and operation of Micro grid.

PO vs CO Mapping:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO206-2.1	2		2							3
CO206-2.2	2		2							3
CO206-2.3	2		2		2					3
CO206-2.4	2		2							3
CO206-2.5	2		2							3

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PS2702	INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- To analyze the motor starting and power factor correction
- To perform computer-aided harmonic design filters
- To expose various grid grounding methodologies
- To perform flicker analysis
- To perform insulation and coordination

PREREQUISITE

- Power System Analysis

- Power System Transients

UNIT I MOTOR STARTINGSTUDIES 9

Introduction – Evaluation Criteria – Starting Methods – System Data - Voltage Drop Calculations- Calculation of Acceleration Time – Motor Starting with Limited - Capacity Generators - Computer- Aided Analysis - Conclusions.

UNIT II POWER FACTOR CORRECTION STUDIES 9

Introduction - System Description and Modeling - Acceptance Criteria - Frequency Scan Analysis - Voltage Magnification Analysis-Sustained Over Voltages – Switching Surge Analysis – Back – to – Back Switching – Summary and Conclusions.

UNIT III HARMONIC ANALYSIS 9

Harmonic Sources – System Response to Harmonics – System Model for Computer - Aided Analysis - Acceptance Criteria - Harmonic Filters - Harmonic Evaluation - Case Study - Summary and Conclusions.

UNIT IV FLICKER ANALYSIS 9

Sources of Flicker – Flicker Analysis – Flicker Criteria – Data for Flicker analysis –Case Study - Arc Furnace Load - Minimizing the Flicker Effects - Summary.

UNIT V INSULATIONAND COORDINATION 9

Modeling of system; simulation of switching surges; description of EMTP – capabilities; voltage acceptance criteria; insulation coordination case study; methods of minimizing switching transients; conclusions.

TEXT BOOKS:

1. Ramasamy Natarajan, “Computer-Aided Power System Analysis”, MarcelDekker Inc.,2002.
2. EMTP literature from www.microtran.cm
3. IEEE paper son bus transfer.

WEB RESOURCES:

1. https://nptel.ac.in/courses/108105067/
2. https://nptel.ac.in/courses/108/101/108101040/
3. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/117105140/lec1.pdf

COURSE OUTCOMES:

CO206-3.1	1.	To analyze the motor starting and power factor correction.
CO206-3.2	2.	To perform computer-aided harmonic design filters.
CO206-3.3	3.	To expose various grid grounding methodologies.
CO206-3.4	4.	To perform computer aided flicker analysis.
CO206-3.5	5.	To expose the insulation and coordination of methods.

POs Vs COs Mapping:

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO206-3.1	**2**	**3**								**2**
CO206-3.2	**2**		**3**							**3**
CO206-3.3	**2**		**3**		**3**			**3**		**3**
CO206-3.4	**2**									
CO206-3.5	**2**									

19PS3701	**ELECTRICAL DISTRIBUTION SYSTEM**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

OBJECTIVES:

- Ability to apply the concepts of planning and design of distribution system for utility systems
- Ability to implement the concepts of voltage control in distribution system.
- Ability to implement the concepts of voltage regulation
- Ability to analyze the power flow in balanced and unbalanced system
- Ability to implement the concepts of voltage feeder analysis.

PRE-REQISITE:

- Transmission system
- Power system Analysis
- Power system operation and control

UNIT I INTRODUCTION 9

Distribution System-Distribution Feeder Electrical Characteristics-Nature of Loads**:** Individual Customer Load, Distribution Transformer Loading and Feeder Load-Approximate Method of Analysis: Voltage Drop, Line Impedance, "*K*" Factors, Uniformly Distributed Loads.

UNIT II DISTRIBUTION SYSTEM PLANNING 9

Factors effecting planning, present techniques, planning models, future nature of distribution planning, Role of computer in Distribution planning. Load forecast, Load characteristics and Load models.

UNIT III DISTRIBUTION SYSTEM LINE MODEL 9

Exact Line Segment Model - Modified Line Model-Approximate Line Segment Model-Modified "Ladder" Iterative Technique-General Matrices for Parallel Lines.

UNIT IV VOLTAGE REGULATION 9

Standard Voltage Ratings-Two-Winding Transformer Theory-Two-Winding Autotransformer-Step-Voltage Regulators: Single-Phase Step-Voltage Regulators-Three-Phase Step-Voltage Regulators- Application of capacitors in Distribution system.

UNIT V DISTRIBUTION FEEDER ANALYSIS 9

Power-Flow Analysis- Ladder Iterative Technique -Unbalanced Three-Phase Distribution Feeder-Modified Ladder Iterative Technique- Load Allocation- Short-Circuit Studies.

TOTAL: 45 PERIODS

REFERENCES

1. William H. Kersting," Distribution System Modeling and Analysis" CRC press 3rd edition,2012.
2. TuranGonen, "Electric Power Distribution System Engineering", McGraw Hill Company. 1986
3. James Northcote – Green, Robert Wilson, "Control and Automation of Electrical Power Distribution Systems", CRC Press, New York, 2007.
4. Pabla H S, "Electrical Power Distribution Systems", Tata McGraw Hill. 2004

WEB SOURCE(S):

- https://nptel.ac.in/courses/108107112/
- https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/108107112/lec1.pdf

COURSE OUTCOME(S):

CO301-1.1	Ability to apply the concepts of planning and design of distribution system for utility system
CO301-1.2	Ability to apply the concepts of distribution system for utility system
CO301-1.3	Ability to implement the concepts of voltage control in distribution system line model
CO301-1.4	Ability to implement the concepts of voltage regulation in distribution system
CO301-1.5	Ability to analyze the power flow in balanced and unbalanced system

PO vs CO Mapping:

CO No	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO301-1.1	2	2								3
CO301-1.2	2	2						3		3
CO301-1.3	2				3			3		3
CO301-1.4	2		2		3					3
CO301-1.5	2		2							3

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PS3702 ENERGY MANAGEMENT AND AUDITING

L	T	P	C
3	0	0	3

OBJECTIVES:

- To study the concepts behind economic analysis and Load management.
- To emphasize the energy management on various electrical equipments and metering.
- To illustrate the concept of lighting systems and cogeneration.

PRE-REQISITE:

- **Electrical Machines**
- **Power System Operation and Control**

UNIT I INTRODUCTION 9

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

UNIT II ENERGY COST AND LOAD MANAGEMENT 9

Important concepts in an economic analysis - Economic models-Time value of money-Utility rate structures- cost of electricity-Loss evaluation- Load management: Demand control techniques-Utility monitoring and control system-HVAC and energy management-Economic justification.

UNIT III ENERGY MANAGEMENT FOR MOTORS, SYSTEMS, AND ELECTRICAL EQUIPMENT 9

Systems and equipment- Electric motors -Transformers and reactors-Capacitors and synchronous machines.

UNIT IV METERING FOR ENERGY MANAGEMENT 9

Relationships between parameters-Units of measure-Typical cost factors- Utility meters - Timing of meter disc for kilowatt measurement - Demand meters -Instrument transformer burdens-

Multitasking solid - state meters – Metering location vs. requirements - Metering techniques and practical examples.

UNIT V LIGHTING SYSTEMS & COGENERATION 9

Concept of lighting systems - The task and the working space -Light sources - Luminaries - Lighting controls-Optimizing lighting energy - Power factor and effect of harmonics on power quality - Cost analysis techniques-Lighting and energy standards Cogeneration: Forms of cogeneration - feasibility of cogeneration- Electrical interconnection.

TOTAL : 45 PERIODS

REFERENCES

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, “Guide to Energy Management”, Fifth Edition, The Fairmont Press, Inc., 2006
2. Eastop T.D & Croft D.R, “Energy Efficiency for Engineers and Technologists”, Logman Scientific & Technical, 1990.
3. Reay D.A, “Industrial Energy Conservation”, 1st edition, Pergamon Press, 1977.
4. “IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities”, IEEE, 1996
5. Amit K. Tyagi, “Handbook on Energy Audits and Management”, TERI, 2003.

WEB RESOURSES:

- https://beeindia.gov.in/sites/default/files/1Ch3.pdf
- https://www.emanz.org.nz/energy-management-audits

COURSE OUTCOMES:

CO301-2.1	Students will develop the ability to learn about the need for energy management and auditing process
CO301-2.2	Learners will learn about basic concepts of economic analysis and load management.
CO301-2.3	Students will understand the energy management on various electrical equipments.
CO301-2.4	Students will have knowledge on the concepts of metering and factors influencing cost

	Function
CO301-2.5	Students will be able to learn about the concept of lighting systems, light sources and various forms of cogeneration

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO301-2.1	**2**	**2**	**1**					**2**		
CO301-2.2	**2**	**2**	**1**					**2**		
CO301-2.3	**2**	**2**	**1**					**2**		
CO301-2.4	**2**	**2**	**1**					**2**		
CO301-2.5	**2**	**2**	**1**					**2**		

1 ➐ Low 2 ➐ Medium 3 ➐ High

		L	T	P	C
19PE3703	**WIND ENERGY CONVERSION SYSTEMS**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To learn the basic concepts of Wind energy conversion system.
- To Introduce the concepts of mathematical modelling and control of the Wind turbine
- To Acquire knowledge on design of Fixed speed system.
- To impart knowledge on Variable speed system and its modelling.
- To learn about Grid integration issues and current practices of wind interconnections with power system

PRE-REQUISITE:

- Power Electronics for Renewable Energy Systems

UNIT I INTRODUCTION **9**

Components of WECS-WECS schemes-Power obtained from wind-simple momentum theory-Power coefficient-Sabinin's theory-Aerodynamics of Wind turbine.

UNIT II WIND TURBINES 9

HAWT- VAWT -Power developed- Thrust- Efficiency- Rotor selection-Rotor design considerations- Tip speed ratio-No. of Blades-Blade profile-Power Regulation-yaw control-Pitch angle control- stall control-Schemes for maximum power extraction.

UNIT III FIXED SPEED SYSTEMS 9

Generating Systems - Constant speed constant frequency systems - Choice of Generators Deciding factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor - Drive Train model- Generator model for Steady state and Transient stability analysis.

UNIT IV VARIABLE SPEED SYSTEMS 9

Need of variable speed systems-Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG - PMSG -Variable speed generators modeling - Variable speed variable frequency schemes.

UNIT V GRID CONNECTED SYSTEMS 9

Wind interconnection requirements, low-voltage ride through (LVRT), ramp rate limitations, and supply of ancillary services for frequency and voltage control, current practices and industry trends wind interconnection impact on steady-state and dynamic performance of the power system including modeling issue.

TOTAL: 45 PERIODS

REFERENCE BOOKS:

1. L.L.Freris “Wind Energy conversion Systems”, Prentice Hall, 1990
2. S.N.Bhadra, D.Kastha ,S.Banerjee, ”Wind Electrical Systems”, Oxford UniversityPress,2010.
3. Ion Boldea, “Variable speed generators”, Taylor & Francis group, 2006.
4. E.W.Golding “The generation of Electricity by wind power”, Redwood burnLtd., Trowbridge,1976.
5. N. Jenkins,” Wind Energy Technology” John Wiley & Sons,1997
6. S.Heir “Grid Integration of WECS”, Wiley 1998.

WEB SOURCES:

5. https://nptel.ac.in/content/storage2/courses/108108078/pdf/chap6/teach_slides06.pdf
6. https://nptel.ac.in/courses/108/105/108105058/

COURSE OUTCOMES:

CO301-3.1 Acquire knowledge on the basic concepts of Wind energy conversion system.

C0301-3.2 Understand the mathematical modelling and control of the Wind turbine

CO301-3.3 Develop more understanding on the design of Fixed speed system

CO301-3.4 Study about the need of Variable speed system and its modelling.

CO301-3.5 Able to learn about Grid integration issues and current practices of wind interconnections with power system.

PO vs CO Mapping

CO No	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO301-3.1	**2**	**2**	**1**		**2**			**2**		
C0301-3.2	**2**	**2**	**1**		**2**			**2**		
CO301-3.3	**2**	**2**	**1**		**2**			**2**		
CO301-3.4	**2**	**2**	**1**		**2**			**2**		
CO301-3.5	**2**	**2**	**1**		**2**			**2**		

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PE3705	**ELECTRIC AND HYBRID VEHICLES**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

OBJECTIVE(s):

1. To acquire knowledge on Basics of an electric hybrid vehicle.
2. To impart knowledge on different battery used in electric vehicle.
3. To Introduce about DC and AC electrical machines used in Electric vehicles
4. To introduce about electric vehicle drive train
5. To introduce about Hybrid electric vehicle.

PRE REQUISTE:

- Electrical Machines-I

- Electrical machines-II
- Electric Circuit Analysis

UNIT I ELECTRIC VEHICLES 9

Introduction, Components, vehicle mechanics – Roadway fundamentals, vehicle kinetics, Dynamics of vehicle motion - Propulsion System Design.

UNIT II BATTERY 9

Basics – Types, Parameters – Capacity, Discharge rate, State of charge, state of Discharge, Depth of Discharge, Technical characteristics, Battery pack Design, Properties of Batteries.

UNIT III DC & AC ELECTRICAL MACHINES 9

Motor and Engine rating, Requirements, DC machines, Three phase A/c machines, Induction machines, permanent magnet machines, switched reluctance machines.

UNIT IV ELECTRIC VEHICLE DRIVE TRAIN 9

Transmission configuration, Components – gears, differential, clutch, brakes regenerative braking, motor sizing.

UNIT V HYBRID ELECTRIC VEHICLES 9

Types – series, parallel and series, parallel configuration – Design – Drive train, sizing of components.

TOTAL: 45 PERIODS

TEXT BOOK(S):

1. Iqbal Hussain, "Electric & Hybrid Vehicles – Design Fundamentals", Second Edition, CRC Press, 2011.
2. James Larminie, "Electric Vehicle Technology Explained", John Wiley & Sons, 2003.

REFERENCE(S):

1. Mehrdad Ehsani, Yimin Gao, Ali Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals", CRC Press, 2010.
2. Sandeep Dhameja, "Electric Vehicle Battery Systems", Newnes, 2000

WEB RESOURCE(S):

- https://nptel.ac.in/courses/108102121/

COURSE OUTCOME(S):

Upon completion of this Course, the students will have the

CO302-1.1 Ability to choose a suitable drive scheme for developing an electric hybrid vehicle depending on resources

CO302-1.2 Ability to design and develop basic schemes of electric vehicles and hybrid electric vehicles

CO302-1.3 Complete knowledge about the electrical machines that can be used for the e-vehicles

CO302-1.4 Ability to design the drive for the e-vehicles.

CO302-1.5 Choose proper energy storage systems for vehicle applications

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO302-1.1	**1**		**1**					**1**		**1**
CO302-1.2	**1**	**2**	**1**		**1**			**2**		**2**
CO302-1.3	**2**		**2**		**2**			**3**		**2**
CO302-1.4	**2**		**2**					**3**		**3**
CO302-1.5	**3**		**3**					**3**		**3**

19PE2707	ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To provide fundamental knowledge on electromagnetic interference and electro magnetic compatibility.
- To study the important techniques to control EMI and EMC.
- To expose the knowledge on testing techniques as per Indian and international standards in EMI measurement.
- To Study the basics of grounding and cables used in power system.
- To understand the concepts of electrostatic discharge, standards and testing techniques.

PRE-REQISITE:

- Electromagnetic Theory
- Transmission and Distribution
- FACTS
- Power System Analysis

UNIT I INTRODUCTION 9

Definitions of EMI/EMC -Sources of EMI- Inter systems and Intra system- Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation typical noise path- EMI predictions and modelling, Cross talk - Methods of eliminating interferences.

UNIT II GROUNDING AND CABLING 9

Cabling- types of cables, mechanism of EMI emission / coupling in cables –capacitive coupling inductive coupling- shielding to prevent magnetic radiation- shield transfer impedance, Grounding – safety grounds – signal grounds- single point and multipoint ground systems hybrid grounds- functional ground layout –grounding of cable shields- -guard shields- isolation, neutralizing transformers, shield grounding at high frequencies, digital grounding- Earth measurement Methods.

UNIT III BALANCING, FILTERING AND SHIELDING 9

Power supply decoupling- decoupling filters-amplifier filtering –high frequency filtering- EMI filters characteristics of LPF, HPF, BPF, BEF and power line filter design -Choice of capacitors, inductors, transformers and resistors, EMC design components -shielding – near and far fields shielding effectiveness- absorption and reflection loss- magnetic materials as a shield, shield discontinuities, slots and holes, seams and joints, conductive gaskets-windows and coatings - grounding of shields.

UNIT IV EMI IN ELEMENTS AND CIRCUITS 9

Electromagnetic emissions, noise from relays and switches, non-linearities in circuits, passive inter modulation, transients in power supply lines, EMI from power electronic equipment, EMI as combination of radiation and conduction.

UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES 9

Static Generation- human body model- static discharges- ESD versus EMC, ESD protection in equipments- standards – FCC requirements – EMI measurements – Open area test site measurements and precautions- Radiated and conducted interference measurements, Control requirements and testing methods.

TOTAL: 45 PERIODS

REFERENCES:

1. V.P. Kodali, “Engineering Electromagnetic Compatibility”, S. Chand, 1996.
2. Henry W.Ott, “ Noise reduction techniques in electronic systems”, John Wiley & Sons, 1989.
3. Bernhard Keiser, “Principles of Electro-magnetic Compatibility”, Artech House, Inc. (685 canton street, Norwood, MA 020062 USA) 1987.
4. Bridges, J.E Milleta J. and Ricketts.L.W., “EMP Radiation and Protective techniques”, John Wiley and sons, USA 1976.
5. William Duff G., & Donald White R. J, “Series on Electromagnetic Interference and Compatibility”, Vol.

Weston David A., “Electromagnetic Compatibility, Principles and Applications”, 1991.

WEB RESOURCES:

- https://www.sebokwiki.org/wiki/Electromagnetic_Interference/Electromagnetic_Compatibility
- https://com-power.com/blog/emi-and-emc-differences
- https://epd.wisc.edu/courses/introduction-to-electromagnetic-interference-and-compatibility-emi-emc/
- https://www.ansys.com/products/electronics/electromagnetic-interference-compatibility
- https://www.slideshare.net/sabeelirshad/electromagnetic-interference-electromagnetic-compatibility

COURSE OUTCOMES:

CO302-2.1	Recognize the sources of Conducted and radiated EMI in Power Electronic Converters and consumer appliances and suggest remedial measures to mitigate the problems.
CO302-2.2	Assess the insertion loss and design EMI filters to reduce the loss.
CO302-2.3	Design EMI filters, common-mode chokes and RC-snubber circuits measures to keep the interference within tolerable limits.
CO302-2.4	Ability to understand the parameters of grounding and cables.
CO302-2.5	Ability to use different standards and testing techniques in electrostatic discharge.

POs Vs COs MAPPING:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO302-2.1	2									
CO302-2.2	2				1					
CO302-2.3	3				2		2			
CO302-2.4	3	2	2	3			2			
CO302-2.5	2		3		3					

1 ❼ Low 2 ❼ Medium 3 ❼ High

19PE2703 **CONTROL SYSTEM DESIGN FOR POWER ELECTRONICS**

L	T	P	C
3	0	0	3

OBJECTIVES:

1. To introduce Modelling of DC-to-DC Power Converters
2. To Study sliding mode controller design
3. To introduce approximate linearization controller design
4. To impart Knowledge on nonlinear controller .
5. To study about predictive control of power converters

PRE -REQUISITE:

- **Power Electronics**
- **Control System**

UNIT I MODELLING OF DC-TO-DC POWER CONVERTERS 9

Modelling of Buck Converter , Boost Converter ,Buck-Boost Converter, Cuk Converter, Sepic Converter, Zeta Converter, Quadratic Buck Converter ,Double Buck-Boost Converter, Boost- Boost Converter General Mathematical Model for Power Electronics Devices

UNIT II SLIDING MODE CONTROLLER DESIGN 9

Variable Structure Systems Single Switch Regulated Systems Sliding Surfaces, Accessibility of the Sliding Surface Sliding Mode Control Implementation of Boost Converter ,Buck-Boost Converter, Cuk Converter, Sepic Converter, Zeta Converter, Quadratic Buck Converter ,Double Buck-Boost Converter, Boost-Boost Converter

UNIT III APPROXIMATE LINEARIZATION CONTROLLER DESIGN 9

Linear Feedback Control, Pole Placement by Full State Feedback , Pole Placement Based on Observer Design ,Reduced Order Observers , Generalized Proportional Integral Controllers, Passivity Based Control , Sliding Mode Control Implementation of Buck Converter , Boost Converter ,Buck-Boost Converter

UNIT IV NONLINEAR CONTROLLER DESIGN 9

Feedback Linearization Isidori's Canonical Form, Input-Output Feedback Linearization, State Feedback Linearization, Passivity Based Control, Full Order Observers, Reduced Order Observers

UNIT V PREDICTIVE CONTROL OF POWER CONVERTERS 9

Basic Concepts, Theory and Methods, Application of Predictive Control in Power Electronics, AC-DC-AC Converter System, Faults and Diagnosis Systems in Power Converters.

TOTAL : 45 PERIODS

WEB RESOURCES:

- https://www.springer.com/gp/book/9788132223276

REFERENCES

1. Hebertt Sira-Ramírez PhD, Ramón Silva-Ortigoza, "Control Design Techniques in Power Electronics Devices", Springer 2012
2. Mahesh Patil, Pankaj Rodey, "Control Systems for Power Electronics: A Practical Guide", Springer India, 2015.
3. Blaabjerg José Rodríguez, "Advanced and Intelligent Control in Power Electronics and Drives" , Springer, 2014
4. Enrique Acha, Vassilios Agelidis, Olimpo Anaya, TJE Miller, "Power Electronic Control in Electrical Systems", Newnes, 2002
5. Marija D. Aranya Chakrabortty, Marija , "Control and Optimization Methods for Electric Smart Grids", Springer, 2012.

COURSE OUTCOMES:

CO302-3.1	Ability to model DC-DC Converter
CO302-3.2	Ability to Design Sliding Mode controller Design
CO302-3.3	Ability to understand an overview on modern linear and nonlinear control strategies for power electronics devices.
CO302-3.4	Ability to understand an overview on modern linear and nonlinear control strategies for power electronics devices.

CO302-3.5 Ability to design appropriate controllers for modern power electronics devices

POs Vs COs MAPPING:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO302-3.1	3		3		2			2		
CO302-3.2	3		3		2			2		
CO302-3.3	3		3		2			2		
CO302-3.4	3		3		2			2		
CO302-3.5	3		3		2			2		

1. **1 ➐ Low 2 ➐ Medium 3 ➐ High**

19PS3703 PRINCIPLES OF ELECTRIC POWER TRANSMISSION L T P C

3 0 0 3

OBJECTIVE(S):

- To understand the modeling of transmission lines
- To introduce the voltage gradients and losses
- To impart knowledge on design of EHV AC and DC transmission lines
- To introduce estimation of the electrostatic field
- To introduce the calculation of the HVDC line parameters

UNIT I INTRODUCTION 9

Standard transmission voltages-AC and DC – different line configurations– average values of line parameters – power handling capacity and line loss – costs of transmission lines and equipment – mechanical considerations in line performance.

UNIT II CALCULATION OF LINE PARAMETERS 9

Calculation of resistance, inductance and capacitance for multi-conductor lines –

calculation of sequence inductances and capacitances – line parameters for different modes of propagation – effect of ground return.

UNIT III VOLTAGE GRADIENTS OF CONDUCTORS 9

Charge - potential relations for multi-conductor lines – surface voltage gradient on conductors – gradient factors and their use – distribution of voltage gradient on sub conductors of bundle - voltage gradients on conductors in the presence of ground wires on towers-I2R loss and corona loss-RIV.

UNIT IV ELECTROSTATIC FIELD AND DESIGN OF EHV LINES 9

Effect of EHV line on heavy vehicles - calculation of electrostatic field of AC lines- effect of high field on humans, animals, and plants - measurement of electrostatic fields – electrostatic Induction in unexercised circuit of a D/C line - induced voltages in insulated ground wires - electromagnetic interference, Design of EHV lines.

UNIT V HVDC LINES 9

Introduction- Reliability and failure issues-Design-tower, ROW, clearances, insulators, electrical and mechanical protection-Maintenance-Control and protection-D.C Electric field and Magnetic field -Regulations and guide lines-underground line design.

TOTAL: 45 PERIODS

TEXT BOOK(S):

1. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", Second Edition, New Age International Pvt. Ltd., 2006.
2. PritindraChowdhari, "Electromagnetic transients in Power System", John Wiley and Sons Inc., 2009.
3. Sunil S.Rao, "EHV-AC, HVDC Transmission & Distribution Engineering", Third Edition, Khanna Publishers, 2008.

REFERENCE(S):

1. William H. Bailey, Deborah E. Weil and James R. Stewart, "A Review on HVDC Power Transmission Environmental Issues", Oak Ridge National Laboratory.

2. J.C Molburg, J.A. Kavicky, and K.C. Picel ,"A report on The design, Construction and operation of Long-distance High-Voltage Electricity Transmission Technologies" Argonne (National Laboratory) 2007.
3. "Power Engineer's Handbook", Revised and Enlarged 6th Edition, TNEB Engineers' Association, October 2002.

WEB RESOURCE(S):

- https://nptel.ac.in/courses/108/102/108102047/

COURSE OUTCOME(S):

At the end of the course, Students will have the:

CO303-1.1 Ability to model the transmission lines

CO303-1.2 Ability to estimate the voltage gradients and losses

CO303-1.3 Ability to design EHV AC and DC transmission lines

CO303-1.4 Ability to estimate the electrostatic field

CO303-1.5 Ability to calculate the HVDC line parameters

POs Vs COs Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO303-1.1	1	1	1					1		1
CO303-1.2	1	2	1		1			2		1
CO303-1.3	2	2	2		2			3		2
CO303-1.4	3	2	3		1			3		2
CO303-1.5	3	1	3					1		3

19PS3704 ADVANCED POWER SYSTEM DYNAMICS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To perform transient stability analysis using unified algorithm.
- To impart knowledge on sub-synchronous resonance and oscillations
- To analyze voltage stability problem in power system.
- To familiarize the methods of transient stability enhancement
- To familiarize the methods of transient stability enhancement and counter measures for sub synchronous resonance

PRE-REQISITE:

- Transmission system
- Power system Analysis
- Power system operation and control

UNIT I TRANSIENT STABILITY ANALYSIS 9

Review of numerical integration methods: Euler and Fourth Order Runge - Kutta methods, Numerical stability and implicit methods, Interfacing of Synchronous machine (variable voltage) model to the transient stability algorithm (TSA) with partitioned – explicit and implicit approaches – Interfacing SVC with TSA-methods to enhance transient stability

UNIT II UNIFIED ALGORITHM FOR DYNAMIC ANALYSIS OF POWER SYSTEMS 9

Need for unified algorithm- numerical integration algorithmic steps-truncation error- variable step size – handling the discontinuities- numerical stability- application of the algorithm for transient. Mid-term and long-term stability simulations

UNIT III SUB SYSNCHRONOUS RESONANCE (SSR) AND OSCILLATIONS 9

Sub synchronous Resonance (SSR) – Types of SSR - Characteristics of series –Compensated transmission systems –Modeling of turbine-generator-transmission network- Self-excitation due to induction generator effect – Torsional interaction resulting in SSR –Methods of analyzing SSR – Numerical examples illustrating instability of sub synchronous oscillations – time-domain simulation of sub synchronous resonance – EMTP with detailed synchronous machine model-

Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters

UNIT IV TRANSMISSION, GENERATION AND LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS 9

Review of transmission aspects – Generation Aspects: Review of synchronous machine theory – Voltage and frequency controllers – Limiting devices affecting voltage stability – Voltage-reactive power characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load Aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.

UNIT V ENHANCEMENT OF TRANSIENT STABILITY AND COUNTER MEASURES FOR SUB SYNCHRONOUS RESONANCE 9

Principle behind transient stability enhancement methods: high-speed fault clearing, reduction of transmission system reactance, regulated shunt compensation, dynamic braking, reactor switching, independent pole-operation of circuit-breakers, single-pole switching, fast-valving, high-speed excitation systems; NGH damper scheme.

TOTAL: 45 PERIODS

REFERENCES

1. R.Ramnujam,” Power System Dynamics Analysis and Simulation”, PHI Learning Private Limited, New Delhi, 2009
2. T.V. Cutsem and C.Vournas, “Voltage Stability of Electric Power Systems”, Kluwer publishers,1998
3. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 1993.
4. H.W. Dommel and N.Sato, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS-91, pp, 1643-1650, July/August 1972.
5. Roderick J . Frowd and J. C. Giri, “Transient stability and Long term dynamics unified”, IEEE Trans., Vol 101, No. 10, October 1982.

6. M.Stubbe, A.Bihain,J.Deuse, J.C.Baader, “A New Unified software program for the study of the dynamic behaviour of electrical power system” IEEE Transaction, Power Systems, Vol.4.No.1,Feb:1989 Pg.129 to 138

WEB SOURCE(S):

- https://nptel.ac.in/courses/108102080/
- https://nptel.ac.in/courses/108101004/

COURSE OUTCOME(S):

CO303-2.1 Learners will be able to understand the transient stability analysis.

CO303-2.2 Learners will have knowledge on unified algorithm for dynamic analysis of power systems

CO303-2.3 Learners will have knowledge on sub synchronous resonance

CO303-2.4 Learners will understand the concepts load aspects of voltage stability analysis

CO303-2.5 Learners will attain basic knowledge on transient stability and counter measures for sub synchronous resonance

PO vs CO Mapping:

CO No	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO303-2.1	2		2							3
CO303-2.2	2				2			3		3
CO303-2.3	2		2					3		3
CO303-2.4	2									3
CO303-2.5	2		2							3

1 ➐ Low 2 ➐ Medium 3 ➐ High

19PS3705	DESIGN OF SUBSTATIONS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To familiarize the methods of transient stability enhancement.
- To provide in-depth knowledge on design criteria of Air Insulated Substation (AIS) and Gas Insulated Substation (GIS).
- To study the substation insulation co-ordination and protection scheme.
- To study the source and effect of fast transients in AIS and GIS

PRE-REQUISITE:

- Engineering Physics
- Transmission and Distribution

UNIT I INTRODUCTION TO AIS AND GIS **9**

Introduction – characteristics – comparison of Air Insulated Substation (AIS) and Gas Insulated Substation (GIS) – main features of substations, Environmental considerations, Planning and installation- GIB / GIL

UNIT II MAJOR EQUIPMENT AND LAYOUT OF AIS AND GIS **9**

Major equipment – design features – equipment specification, types of electrical stresses, mechanical aspects of substation design- substation switching schemes- single feeder circuits; single or main bus and sectionalized single bus- double main bus-main and transfer bus- main, reserve and transfer bus- breaker-and-a- half scheme-ring bus

UNIT III INSULATION COORDINATION OF AIS AND GIS **9**

Introduction – stress at the equipment – insulation strength and its selection – standard BILs – Application of simplified method – Comparison with IEEE and IEC guides.

UNIT IV GROUNDING AND SHIELDING **9**

Definitions – soil resistivity measurement – ground fault currents – ground conductor – design of substation grounding system – shielding of substations – Shielding by wires and masts.

UNIT V FAST TRANSIENTS PHENOMENON IN AIS AND GIS 9

Introduction – Disconnector switching in relation to very fast transients – origin of VFTO – propagation and mechanism of VFTO – VFTO characteristics – Effects of VFTO.

TOTAL : 45 PERIODS

REFERENCE BOOKS:

1. Andrew R. Hileman, "Insulation coordination for power systems", Taylor and Francis, 1999.
2. M.S. Naidu, "Gas Insulation Substations", I.K. International Publishing House Private Limited, 2008.
3. Klaus Ragallar, "Surges in high voltage networks" Plenum Press,New York, 1980.
4. "Power Engineer's handbook", TNEB Association.
5. PritindraChowdhuri, "Electromagnetic transients in power systems", PHI Learning Private Limited, New Delhi, Second edition, 2004.
6. "Design guide for rural substation", United States Department of Agriculture, RUS Bulletin, 1724E-300, June 2001.
7. AIEE Committee Report, "Substation One-line Diagrams," AIEE Trans. On Power Apparatus and Systems, August 1953.
8. Hermann Koch, "Gas Insulated Substations", Wiley-IEEE Press, 2014.

WEB SOURCES:

7. https://nptel.ac.in/courses/108107112/
8. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/108102047/lec23.pdf
9. https://nptel.ac.in/content/storage2/courses/108107028/module1/lecture1/lecture1.pdf

COURSE OUTCOMES:

CO303-3.1 Able to apply Awareness towards substation equipment and their arrangements.

C0303-3.2 Able to design the substation for present requirement with proper insulationcoordination and protection against fast transients.

CO303-3.3 Develop more understanding about insulation concepts

CO303-3.4 Acquire knowledge about grounding and shielding methods

CO303-3.5 Understand about fast transient phenomenon in power system.

PO vs CO Mapping

CO No	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO303.1	3	3	3		2			3		2
C0303.2	3	3	3		2			3		2
CO303.3	3	3	3		2			3		2
CO303.4	3	3	3		2			3		2
CO303.5	3	3	3		2			3		2

1 ❼ Low 2 ❼ Medium 3 ❼ High