KAMARAJ COLLEGE OF ENGINEERING & TECHNOLOGY
(An Autonomous Institution - AFFILIATED TO ANNA UNIVERSITY, CHENNAI)
S.P.G.Chidambara Nadar - C.Nagammal Campus
S.P.G.C.Nagar, K.Vellakulam - 625 701, (Near Virudhunagar), Madurai District.

Department of Electrical and Electronics Engineering

M.E. Power Systems Engineering

(Regulations 2020 – Autonomous)

Vision of the Department:

To make the Department of Electrical and Electronics Engineering of this Institution the unique of its kind in the field of Research and Development activities in this part of the world.

Mission of the Department:

To impart highly innovative and technical knowledge in the field of Electrical and Electronics Engineering to the urban and unreachable rural student folks through Total Quality Education.

Program Educational Objectives (PEOs):

PEO 1: Graduates of the programme will have an enlightening career in core field of Power Systems Engineering.

PEO 2: Graduates of the programme will demonstrate their practical skills by undergoing innovative research in recent trends of Power Systems Engineering.

PEO 3: Graduates of the programme will practice ethics and exhibit project management skills to work in collaborative and multi-disciplinary tasks.

PEO 4: Graduates of the programme will demonstrate lifelong independent learning skills and thereby pursue higher studies in reputed institutions.

Program Specific Outcomes (PSOs):

PSO 1: Ability to apply the various principles of Power Systems Engineering to analyze and solve real time problems existing in the power industry.

PSO 2: Ability to acquire abreast knowledge in the emerging technologies of Power Systems Engineering and demonstrate the skills acquired in developing quality products in scientific and business applications.

The credit requirement for the programme M.E. Power Systems Engineering (as per Regulation 2020) is outlined below:

SEMESTER I

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
Theory								
1.	MA1103	Applied Mathematics for Power System Engineers	FC	4	3	1	0	4
2.	PS1101	Advanced Power System Operation and Control	PC	3	3	0	0	3
3.	PS1102	Computer Aided Power System Analysis (Theory Cum Laboratory)	PC	5	3	0	2	4
4.	PS1103	Electromagnetic Transients in Power Systems	PC	3	3	0	0	3
5.	PS1104	System Theory	PC	4	3	1	0	4
6.		Professional Elective I	PE	3	3	0	0	3
			Total	**22**	**18**	**2**	**2**	**21**

SEMESTER II

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
Theory								
1.	PS1201	Advanced Power System Protection	PC	3	3	0	0	3
2.	PS1202	Extra High Voltage AC and DC Transmission	PC	3	3	0	0	3
3.	PS1203	Power System Deregulation	PC	3	3	0	0	3
4.	PS1204	Power System Dynamics	PC	4	3	1	0	4
5.		Professional Elective II	PE	3	3	0	0	3
6.		Online Course (NPTEL / SWAYAM)	OL	3	3	0	0	3
Practical								
7.	PS1211	Advanced Power System Simulation Laboratory	PC	4	0	0	4	2
8.	PS1221	Technical Paper Writing and Patent Filing	EEC	3	1	0	2	2
			Total	**26**	**19**	**1**	**6**	**23**

SEMESTER III

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
Theory								
1.		Professional Elective III	PE	3	3	0	0	3
2.		Professional Elective IV	PE	3	3	0	0	3
3.		Open Elective I*	OE	3	3	0	0	3
Practical								
4.	PS1321	Project Work Phase I	EEC	12	0	0	12	6
			Total	**21**	**9**	**0**	**12**	**15**

* Open Elective : Industry Certification Courses (for promoting Interdisciplinary)

SEMESTER IV

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
Practical								
1.	PS1421	Project Work Phase II	EEC	24	0	0	24	12
			Total Credits	**24**	**0**	**0**	**24**	**12**

Semester wise Credits	**I**	**II**	**III**	**IV**	**Total Credits**
	21	**23**	**15**	**12**	**71**

Foundation Courses (FC)

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
1.	MA1103	Applied Mathematics for Power System Engineers	FC	4	3	1	0	4

Professional Core Courses (PC)

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
1.	PS1101	Advanced Power System Operation and Control	PC	3	3	0	0	3
2.	PS1102	Computer Aided Power System Analysis (Theory Cum Laboratory)	PC	5	3	0	2	4
3.	PS1103	Electromagnetic Transients in Power Systems	PC	3	3	0	0	3
4.	PS1104	System Theory	PC	4	3	1	0	4
5.	PS1201	Advanced Power System Protection	PC	3	3	0	0	3
6.	PS1202	Extra High Voltage AC and DC Transmission	PC	3	3	0	0	3
7.	PS1203	Power System Deregulation	PC	3	3	0	0	3
8.	PS1204	Power System Dynamics	PC	4	3	1	0	4
9.	PS1211	Advanced Power System Simulation Laboratory	PC	4	0	0	4	2

Professional Elective Courses (PE)

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
Professional Elective I (1st Semester)								
1.	PS1131	Computer Aided Design of Electrical Apparatus	PE	3	3	0	0	3
2.	PS1132	Industrial Power System Analysis and Design	PE	3	3	0	0	3
3.	PS1133	Nano Materials and Applications of High Voltage Engineering	PE	3	3	0	0	3
4.	PS1134	Power System Planning and Reliability	PE	3	3	0	0	3

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
5.	PS1135	Power System Voltage Stability	PE	3	3	0	0	3
6.	PS1136	Solar and Energy Storage Systems	PE	3	3	0	0	3
Professional Elective II (2nd Semester)								
1.	PS1231	AI Techniques for Power Systems	PE	3	3	0	0	3
2.	PS1232	Distributed Generation and Microgrid	PE	3	3	0	0	3
3.	PS1233	Electric Vehicles and Power Management	PE	3	3	0	0	3
4.	PS1234	Energy Management and Auditing	PE	3	3	0	0	3
5.	PS1235	Flexible AC Transmission Systems	PE	3	3	0	0	3
6.	PS1236	Wind Energy Conversion Systems	PE	3	3	0	0	3
Professional Elective III (3rd Semester)								
1.	PS1331	Electromagnetic Field Computation and Modelling	PE	3	3	0	0	3
2.	PS1332	Power Quality Assessment and Mitigation	PE	3	3	0	0	3
3.	PS1333	Power System Optimization	PE	3	3	0	0	3
4.	PS1334	Power System State Estimation	PE	3	3	0	0	3
5.	PS1335	SCADA and DCS	PE	3	3	0	0	3
6.	PS1336	Smart Grid Technologies	PE	3	3	0	0	3
Professional Elective IV (3rd Semester)								
1.	PS1337	Application of Power Electronics in Power Systems	PE	3	3	0	0	3
2.	PS1338	Control and Protection of Microgrid	PE	3	3	0	0	3
3.	PS1339	Design of Substations	PE	3	3	0	0	3
4.	PS1340	Electrical Safety & Hazard Management	PE	3	3	0	0	3
5.	PS1341	Energy Efficient Building Management Systems	PE	3	3	0	0	3
6.	PS1342	IoT for Power Engineers	PE	3	3	0	0	3

Employability Enhancement Courses (EEC)

S. No.	Course Code	Course Name	Category	Contact Periods	Credits			
					L	T	P	C
1.	PS1221	Technical Paper Writing and Patent Filing	EEC	3	1	0	2	2
2.	PS1321	Project Work Phase I	EEC	12	0	0	12	6
3.	PS1421	Project Work Phase II	EEC	24	0	0	24	12

S. No.	Course Code	Course Name	Credits			
			L	T	P	C
1.	PS1221	Technical Paper Writing and Patent Filing	1	0	2	2
2.	PS1321	Project Work Phase I	0	0	12	6
3.	PS1421	Project Work Phase II	0	0	24	12

S. No.	Category of Courses	I	II	III	IV	Credits
1.	**Foundation Courses (FC)**	4	-	-	-	**4**
2.	**Professional Core Courses (PC)**	14	15	-	-	**29**
3.	**Professional Elective Courses (PE)**	3	3	6	-	**12**
4.	**Open Elective Courses (OE)**	-	-	3	-	**3**
5.	**Employability Enhancement Courses (EEC)**	-	2	6	12	**20**
6.	**Online Courses (OL)**	-	3	-	-	**3**
	Semester wise Credits	**21**	**23**	**15**	**12**	**-**
					Total Credits	**71**

MA1103 APPLIED MATHEMATICS FOR POWER SYSTEM ENGINEERS

L	T	P	C
3	1	0	4

OBJECTIVES:

- 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
- 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.

UNIT I MATRIX THEORY 12

Generalized Eigenvectors - Canonical basis - Least squares method - Singular value decomposition. – Introduction to Sparse Matrix - 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 CALCULUS OF VARIATIONS 12

Concept of variation and its properties – Euler's equation – Functional dependent on first and higher order derivatives – Functional dependent on functions of several independent variables – 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

UNITV 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 – Eigenvalue problems and orthogonal functions – Regular Sturm - Liouville systems

TOTAL: 60 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Understand the concepts of decomposition of the matrices into required form.

CO2: Apply the concept of calculus of variations in solving boundary value problems

CO3: Apply the concept of the probability distributions in engineering problems.

CO4: Develop a linear programming model from problem description, apply the simplex method for solving linear programming problems.

CO5: Solve problems using Fourier Series associated with electrical engineering problems.

REFERENCES:

1. Andrews, L.C. and Phillips, R.L., 2003. *Mathematical techniques for engineers and scientists* (Vol. 118). Spie Press.
2. Bronson, R. 2011. *Matrix Operation*, Schaum's outline series, 2nd Edition, McGraw Hill.
3. Elsgolc, L.D., 2012. *Calculus of variations*. Courier Corporation.
4. Johnson, R.A., Miller, I. and Freund, J.E., 2000. *Probability and statistics for engineers* (Vol. 2000, p. 642p). London: Pearson Education.

PS1101	ADVANCED POWER SYSTEM OPERATION AND CONTROL	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To understand the fundamentals of Economic operation and the control of generation.
- To impart knowledge about Economic Dispatch, Unit commitment and hydrothermal scheduling and solution techniques.
- To impart knowledge on the need of power system security and state estimation and its role in the day to day operation of power system.

UNIT I ECONOMIC DISPATCH OF THERMAL UNITS AND METHODS OF SOLUTION 9

Economic importance – Characteristics of steam units. –Economic Dispatch Problem - Thermal System Dispatching with Network Losses Considered - Lambda-Iteration Method - Gradient Methods of Economic Dispatch: Gradient Search, Newton's Method - Economic Dispatch Using Dynamic Programming - Composite Generation Production Cost Function- Base Point and Participation Factors - Locational Marginal Price - Auction Mechanisms.

UNIT II UNIT COMMITMENT 9

Economic Dispatch versus Unit Commitment - Constraints in Unit Commitment - Spinning Reserve - Thermal Unit Constraints - Other Constraints: Hydro-Constraints, Must Run, Fuel Constraints - Unit Commitment Solution Methods: Priority-List Methods, Dynamic-Programming Solution: Forward DP Approach, Lagrange Relaxation Solution - Mixed Integer Linear Programming - Security-Constrained Unit Commitment (SCUC) – Daily Auctions Using a Unit Commitment.

UNIT III HYDROTHERMAL SCHEDULING PROBLEM 9

Hydrothermal scheduling problem: Long-Range Hydro-Scheduling, Short-Range Hydro-Scheduling, - Hydroelectric Plant Models: Scheduling Energy, Short-Term Hydrothermal Scheduling Problem, Short-Term Hydro-Scheduling: A Gradient Approach - Pumped-Storage Hydro plants - Dynamic-Programming Solution to the Hydrothermal Scheduling Problem

UNIT IV CONTROL OF GENERATION 9

Generator Model - Load Model- Prime-Mover Model - Governor Model - Tie-Line Model - Generation Control: Supplementary Control Action, Tie-Line Control, Generation Allocation, Automatic Generation Control (AGC) Implementation, AGC Features.

UNIT V POWER SYSTEM SECURITY AND STATE ESTIMATION 9

Factors Affecting Power System Security- Contingency Analysis: Detection of Network Problems, Linear Sensitivity Factors, Power System State Estimation – DC state estimation model- Maximum

Likelihood Weighted Least-Squares Estimation - Bad data detection and identification. - Network observability - Application of Power Systems State Estimation

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Explain thermal unit characteristics and their economic operation.

CO2: Customize conventional optimization techniques for Unit Commitment problem with various constraints.

CO3: Describe the significance of hydrothermal scheduling and different solution methods

CO4: Explain generation control and solve AGC problems

CO5: Infer the needs of power system security and state estimation in real time operation

REFERENCES:

1. Wood, A.J., Wollenberg, B.F. and Sheblé, G.B., 2013. *Power generation, operation, and control*. John Wiley & Sons.
2. John Grainger, J. and Stevenson Jr, W., 2003. D. Power System Analysis.
3. PSR Murthy, 2009. *Operation & Control in Power System*, BS Publications, 2nd edition.

PS1102	**COMPUTER AIDED POWER SYSTEM ANALYSIS (Theory Cum Laboratory)**	**L**	**T**	**P**	**C**
		3	**0**	**2**	**4**

OBJECTIVES:

- To impart in-depth knowledge on different methods of power flow solutions.
- To perform optimal power flow solutions in detail.
- To Understand power system security concepts and study the methods to rank the contingencies
- To perform short circuit fault analysis and understand the consequence of different type of faults.
- To analyze computer based approach of different numerical integration methods and factors influencing transient stability

UNIT I AC POWER FLOW ANALYSIS 9

Newton- Raphson method- Decoupled method and Fast Decoupled Power Flow method for load flow analysis; Adjustment of P-V buses; Sensitivity factors for P-V bus adjustment- Power system equivalence - Load flow under power electronic control

Exp: Power flow analysis by Newton-Raphson method and Fast decoupled method

UNIT II OPTIMAL POWER FLOW 9

Basic concepts of real and reactive power flow- Problem statement; Optimal Power flow- DC, Single phase AC and three phase AC; 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.

Exp: Optimal Power Flow of a simple Three Bus System.

UNIT III POWER SYSTEM SECURITY 9

Introduction to Power system security analysis and monitoring - DC Load flow - Factors affecting power system security - Contingency analysis for generator and line outages using linear sensitivity factors. **Exp:** Contingency analysis: Generator shift factors and line outage distribution factors

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- Short circuit capacity of a bus and circuit breaker rating -Open circuit faults

Exp: (a) Digital Over Current Relay Setting and Relay Coordination using Suitable software Packages.

(b) Co-ordination of over-current and distance relays for radial line protection

UNIT V A COMPUTER BASED APPROACH FOR TRANSIENT STABILITY ANALYSIS 9

Importance of stability analysis in power system- Classification of power systems stability- Numerical Integration Methods: Modified Euler and Fourth Order Runge- Kutta methods, Algorithm for simulation of SMIB and multi-machine system with classical synchronous machine model; Multi-machine transient stability analysis (Qualitative treatment only), Factors influencing transient stability, Numerical stability and implicit Integration methods.

Exp: (a) Transient stability analysis of multi machine power system with classical machine model.

(b) Analysis of switching surge using EMTP: Energisation of a long distributed- parameter line.

(c) Analysis of switching surge using EMTP: Computation of transient recovery voltage for short line fault.

TOTAL: 45+30=75 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Formulate the power flow problem and solve using numerical iterative methods.

CO2: Illustrate DC & AC Optimum power flow.

CO3: Analyze power system studies that are needed for the transmission system planning.

CO4: Analyze power systems under abnormal (fault) conditions

CO5: Classify power system stability and derive the swing equation for SMIB system and to assess the transient stability of given SMIB system by appropriate technique.

REFERENCES:

1. Wood, A.J., Wollenberg, B.F. and Sheblé, G.B., 2013. *Power generation, operation, and control*. John Wiley & Sons.
2. 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.
3. Zollenkopf, K., 1970. Bi-factorization-basic ional algorithm and programming techniques. In *Conference on Large Sets of Sparse Equations, Oxford*.
4. Pai, M.A. and Chatterjee, D., 2014. *Computer techniques in power system analysis*. McGraw-Hill Education (India).
5. Stagg, G.W. and El-Abiad, A.H., 1968. *Computer methods in power system analysis*. McGraw-Hill.
6. Natarajan, R., 2002. *Computer-aided power system analysis*. CRC Press.
7. Kundur, P., Balu, N.J. and Lauby, M.G., 1994. *Power system stability and control* (Vol. 7). New York: McGraw-hill.

PS1103 **ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS**

L	T	P	C
3	0	0	3

OBJECTIVES:

- To impart in depth knowledge about various power system transients and analyze the Travelling wave phenomena.
- To impart knowledge on the Lighting, Switching and Temporary Over voltages
- To impart knowledge on modeling parameters in overhead lines
- To impart knowledge on modeling parameters in underground cables.
- To describe the methodology for computing the transients in power systems

UNIT I REVIEW OF POWER SYSTEM TRANSIENTS AND TRAVELLING WAVE PHENOMENA 9

Introduction to power system transients: impulsive and oscillatory transients Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behavior of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion.

UNIT II LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES 9

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

UNIT III PARAMETERS AND MODELING OF OVERHEAD LINES 9

Review of line 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.

UNIT IV PARAMETERS AND MODELING OF UNDERGROUND CABLES 9

Distinguishing features of underground cables: technical features, electrical parameters, overhead lines versus underground cables; cable types; series impedance and shunt admittance of single-core self-contained cables, impedance and admittance matrices for three phase system formed by three single-core self-contained cables; approximate formulas for cable parameters

UNIT V COMPUTATION OF POWER SYSTEM TRANSIENTS 9

Digital computation of line parameters: why line parameter evaluation programs? salient features of a typical line parameter evaluation program; constructional features of that 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 various types of transients using PSCAD/ EMTP and insulation co-ordination.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Analyze the different types of power system transients and travelling wave concepts.
CO2: Explain the concepts of impulsive transients such as lightning, switching
CO3: Describe modeling parameters of overhead transmission lines.
CO4: Describe modeling parameters of underground cables
CO5: Compute different types of transients in power systems using PSCAD/EMTP.

REFERENCES:

1. Greenwood, A., 1991. Electrical transients in power systems.
2. Ramanujam, R., 2014. Computational Electromagnetic Transients: Modeling, Solution Methods and Simulation.
3. Pritindra Chowdhari, 2009. *Electromagnetic transients in Power System*, John Wiley and Sons Inc., Second Edition,
4. Rakosh Das Begamudre, 1990. *Extra High Voltage AC Transmission Engineering*, (Second edition) Newage International (P) Ltd., New Delhi.

PS1104	SYSTEM THEORY	L	T	P	C
		3	1	0	4

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

UNIT I STATE VARIABLE REPRESENTATION 12

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 12

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 12

Controllability and Observability definitions and Kalman rank conditions -Stabilizability and Detectability-Test for Continuous time Systems- Time varying and Time invariant case- Output Controllability-Reducibility- System Realizations.

UNIT IV STATE FEEDBACK CONTROL AND STATE ESTIMATOR 12

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

UNIT V LYAPUNOV STABILTY ANALYSIS 12

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 – Krasovskii's and Variable-Gradiant Method.

TOTAL: 60 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Outline the concept of State-State equation for Dynamic Systems and the uniqueness of state model

CO2: Demonstrate the solution of linear and nonlinear time varying state equation

CO3: Analyze Controllability and Observability for time varying and time invariant systems.

CO4: Design state feedback controller and state observers for SISO and MIMO systems.

CO5: Analyze the stability of LTI systems in the sense of Lyapunov.

REFERENCES:

1. Gopal, M., 1993. *Modern control system theory*. New Age International.
2. Ogata, K. and Yang, Y., 2002. *Modern control engineering* (Vol. 4). India: Prentice hall.
3. Bay, J., 1999. Fundamentals of linear state space systems.
4. Choudhury, D.R., 2005. *Modern control engineering*. PHI Learning Pvt. Ltd..
5. Houpis, C.H. and Sheldon, S.N., 2013. *Linear Control System Analysis and Design with MATLAB®*. CRC Press.
6. Bubnicki, Z., 2005. *Modern control theory* (Vol. 2005925392). Berlin: Springer..
7. Chen, C.T., 1999. Linear system theory and design: Oxford University Press. *New York, USA*.
8. Vidyasagar, M., 2002. *Nonlinear systems analysis*. Society for Industrial and Applied Mathematics.

PS1201	ADVANCED POWER SYSTEM PROTECTION	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To describe about the various schemes of Over current protection
- To illustrate concepts of transformer protection
- To analyze distance and carrier protection
- To familiarize the concepts of Bus bar protection and Numerical protection
- To understand the concepts of adaptive relaying

UNIT I OVER CURRENT & EARTH FAULT PROTECTION 9

Introduction - operating principles - Time - Current characteristics - Current setting - Time setting-- Concept of Coordination - Reverse power or directional relay - Protection of parallel / ring feeders - Combined Earth fault and phase fault protection scheme - Static over current relays - Numerical over current protection; numerical coordination example for a radial feeder

UNIT II TRANSFORMER & BUSBAR PROTECTION 9

Types of Differential Protection – High Impedance protection - External fault with one CT saturation - Actual behaviors of a protective CT - Circuit model of a saturated CT - Need for high impedance - Percentage Differential Bias Characteristics - Inrush phenomenon - Zero Sequence filtering - High resistance Ground Faults in Transformers – Restricted Earth fault Protection - Transformer protection application chart.

Differential protection of busbars external and internal fault - Supervisory relay-protection of three phase busbars - Numerical examples on design of high impedance busbar differential scheme Characteristics - Comparison between Transformer differential &Busbar differential protection schemes.

UNIT III DISTANCE AND CARRIER PROTECTION OF TRANSMISSION LINES 9

Drawback of over – Current protection – Introduction to distance relay - Distance protection of a three – Phase line-reasons for inaccuracy of distance relay reach - Three stepped distance protection - Trip contact configuration for the three - Stepped distance protection.

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

Various faults and abnormal operating conditions – Stator Winding Faults – Protection against Stator (earth) faults – third harmonic voltage protection – Rotor fault – Abnormal operating conditions - Protection against Rotor faults - Loss of excitation – Protection against Mechanical faults; Numerical examples for typical generator protection schemes

UNITV RELAY TESTING AND ADAPTIVE RELAYING 9

Testing of Relays- Field test procedures for protective relays. Adaptive relaying- AI & Fuzzy Based Protection, Intelligent Transmission Line Relaying Fault Detection.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Deduce the operation and characteristics of Overcurrent protection and earth fault protection schemes.

CO2: Outline the various schemes in Transformer protection with suitable illustrations.

CO3: Describe the operating principle of Distance and Carrier protection in transmission lines.

CO4: Summarize the schemes of Generator protection under various fault conditions.

CO5: Outline the concept of adaptive relaying with suitable illustrations.

REFERENCES:

1. Paithankar, Y.G. and Bhide, S.R., 2011. *Fundamentals of power system protection*. PHI Learning Pvt. Ltd..
2. Madhava Rao, T.S., 1989. Power System Protection Static Relays With Microprocessor Applications.
3. Johns, A.T. and Salman, S.K., 1995. *Digital protection for power systems* (No. 15). IET.
4. Ziegler, G., 2011. *Numerical distance protection: principles and applications*. John Wiley & Sons.
5. *Lakervi, E. and Holmes, E.J., 1995. Electricity distribution network design (No. 21). IET.*
6. Ram, B., 2001. Vishwakarma,'Power System Protection and Switchgear'.
7. Singh, L.P., 2006. *Digital Protection Protective Relaying From Electromechanical To Microprocess*. New Age International.
8. Elmore, W.A., 2003. *Protective relaying: theory and applications* (Vol. 1). CRC press.
9. Phadke, A.G. and Thorp, J.S., 2009. *Computer relaying for power systems*. John Wiley & Sons.
10. Inc Institute of Electrical and Electronics Engineers, 1986. *IEEE Recommended Practice for Protection and Coordination of Indusrial and Commercial Power Systems*. Institute of Electrical and Electronics Engineers, Incorporated.

PS1202	EXTRA HIGH VOLTAGE AC AND DC TRANSMISSION	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To introduce the extra high voltage AC and DC transmission.
- To learn about the properties of bundle conductors and voltage control using compensators.
- To introduce the HVDC transmission system with types, control and protection.
- To discuss about the design factors of lines and cables.
- To learn about the overvoltage problem in extra high voltage system.

UNIT I INTRODUCTION 9

Introduction to EHV AC and DC transmission -Role of EHV AC Transmission - Standard Transmission Voltages - Power-Handling Capacity and Line Loss - comparison between HVAC and HVDC overhead and underground transmission schemes - Factors concerning choice of HVAC and HVDC transmission - Block diagram of HVAC and HVDC transmission schemes.

UNIT II EHV AC TRANSMISSION 9

Types of conductors - Properties of bundled conductors - Surface voltage gradient on single and multi-conductor bundles - Corona effects - Power loss - Charge voltage diagram with Corona - Noise generation and their characteristics - Corona pulses, their generation and properties (qualitative study only)- Problems of EHV AC transmission at power frequency - Voltage control using compensators - Cascade connection of components.

UNIT III HVDC TRANSMISSION 9

HVDC links in India - Analysis of DC transmission systems - Harmonics on AC and DC sides and filters for their suppression - Multi terminal D.C. Transmission systems; application, types, control and protection - Parallel operation of A.C. and D.C. transmission - Voltage stability in AC/DC systems - Modern developments in HVDC transmission - HVDC systems simulation. Case study of 500kV, 2500 MW, HVDC Ballia – Bhiwadi transmission link.

UNIT IV EHV LINES AND CABLE TRANSMISSION 9

Electrical Characteristics of EHV Cables - Properties of Cable-Insulation Materials - Breakdown and Withstand Electrical Stresses in Solid Insulation-Statistical Procedure - Design Basis of Cable Insulation - Tests on Cable Characteristics- Surge Performance of Cable Systems -Gas Insulated EHV Lines- Design factors under steady state - Design basis of cable insulation.

UNITV DESIGN & TESTING OF EHV SYSTEMS 9

General layout of EHV laboratory.-Design of EHV Lines - Design factors under steady state-steady state limits - Line insulation coordination based upon transient over voltages - Design examples. EHV Testing - Standard specifications and standard waveshapesfor testing - Generation of switching surges for transformer testing - Impulse voltage generators - Generation of impulse currents.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Compare HVAC and HVDC for overhead and underground transmission system.

CO2: Derive the surface voltage gradient of single, double, and more than three conductor bundles and expression for a charge voltage diagram for evaluation of the power loss.

CO3: Analyze the DC transmission system in case of harmonics and discuss about the multi terminal DC transmission system.

CO4: Illustrate concepts in design of EHV lines and cable transmission.

CO5: Discuss about protection of HVAC and HVDC systems.

REFERENCES:

1. Begamudre, R.D., 2006. *Extra high voltage AC transmission engineering*. New Age International.
2. Rao, S., 2009. *EHV-AC, HVDC transmission & distribution engineering: theory, practice and solved problems*. Khanna publishers.
3. Padiyar, K.R., 1990. *HVDC power transmission systems: technology and system interactions*. New Age International.
4. Kuffel, J. and Kuffel, P., 2000. *High voltage engineering fundamentals*. Elsevier.

PS1203	POWER SYSTEM DEREGULATION	L	T	P	C
		3	0	0	3

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 locational marginal pricing and financial transmission rights.
- To Illustrate about various power sectors in India

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 costs of 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, Features of 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 area congestion management – Capacity alleviation method.

UNIT III LOCATIONAL MARGINAL PRICES AND FINANCIAL TRANSMISSION RIGHTS 9

Mathematical preliminaries: - Locational marginal pricing– Lossless 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 adequacy – FTR issuance process: FTR auction, FTR allocation – Treatment of revenue shortfall – 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 – Types of 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 –Cooptimization of energy and reserve services - Transmission pricing – Principles – Classification – Rolled in transmission pricing methods – Marginal transmission pricing paradigm – Composite pricing paradigm – Merits and demerits of different paradigm

UNIT V REFORMS IN INDIAN POWER SECTOR 9

Introduction – Framework 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

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Explain about the fundamental concepts in restructuring of power industry.
CO2: Describe the various methods of congestion management.
CO3: Outline about locational margin prices and financial transmission rights.
CO4: Interpret the significance ancillary services and pricing of transmission network.
CO5: Outline the concept of various power sectors in India.

REFERENCES:

1. Paithankar, Y.G. and Bhide, S.R., 2011. *Fundamentals of power system protection*. PHI Learning Pvt. Ltd.
2. Shahidehpour, M. and Alomoush, M., 2017. *Restructured electrical power systems: Operation: Trading, and volatility* (Vol. 1). CRC Press.

3. Bhattacharya, K., Bollen, M.H. and Daalder, J.E., 2012. *Operation of restructured power systems*. Springer Science & Business Media.
4. Paranjothi, S.R. 2017. *Modern Power Systems*, New Age International.
5. Hunt, S., 2002. *Making competition work in electricity* (Vol. 146). John Wiley & Sons.
6. Stoft, S., 2002. *Power System Economics: Designing Markets for Electricity*, Wiley-IEEE
7. Indian Energy Exchange Limited, URL: www.iexindia.com

PS1204	POWER SYSTEM DYNAMICS	L	T	P	C
		3	1	0	4

OBJECTIVES:

- To impart knowledge on dynamic modeling of a synchronous machine in detail.
- To describe the modeling of excitation and speed governing system in detail.
- To understand the fundamental concepts of small disturbance stability of dynamic systems.
- To expose the students to basic concepts of voltage stability.
- To understand and enhance small signal stability problem of power systems.

UNIT I SYNCHRONOUS MACHINE MODELLING 15

Schematic Diagram - Physical Description - Mathematical Description of a Synchronous Machine- The dq0 Transformation - Per Unit Representations - Equivalent Circuits for direct and quadrature axes - Steady-state Analysis - Equations of Motion - Swing Equation - calculation of inertia constant - Synchronous Machine Representation in Stability Studies - Simplifications for large-scale studies - Simplified model with amortisseurs neglected – Constant flux linkage model.

UNIT II MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS 12

Excitation System Requirements - Elements of an Excitation System; Types of Excitation System - Control and protective functions - Turbine and Governing System Modeling: Functional Block Diagram of Power Generation and Control - Schematic of a hydroelectric plant - classical transfer function of a hydraulic turbine - Governor for Hydraulic Turbine - Steam turbine modeling - Single reheat tandem compounded type.

UNIT III SMALL-SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS 12

Classification of Stability - Fundamental Concepts of Stability of Dynamic Systems - Eigen properties of the state matrix - Single-Machine Infinite Bus (SMIB) Configuration - Classical Machine Model stability analysis with numerical example - Effects of Field Circuit Dynamics - Effect of field flux variation on system stability - analysis with numerical example.

UNIT IV SMALL-SIGNAL STABILITY ANALYSIS WITH CONTROLLERS 12

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- Illustration of stability analysis using a numerical example - Principle behind small signal stability improvement methods - delta-omega and delta P-omega stabilizers.

UNIT V VOLTAGE STABILITY ANALYSIS 9

Classification of Voltage Stability-Basic Concept Related To Voltage Stability - Transmission System Characteristics - Generator Characteristics - Load Characteristics - Characteristics of

Reactive Compensating Devices- Typical Scenario of Voltage Collapse -Voltage Stability Analysis- Dynamic Analysis - Static Analysis-Prevention Of Voltage Collapse.

TOTAL: 60 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Explain the detailed modelling of synchronous machine used in stability studies.

CO2: Describe the modeling of excitation and speed governing system for stability analysis.

CO3: Illustrate the significance of small signal stability analysis without controllers in SMIB system with numerical example

CO4: Illustrate the significance of small signal stability analysis with controllers in SMIB system with numerical example

CO5: Investigate the concept of voltage stability of power system.

REFERENCES:

1. Sauer, P.W., Pai, M.A. and Chow, J.H., 2017. *Power system dynamics and stability: with synchrophasor measurement and power system toolbox*. John Wiley & Sons.
2. Kundur, P., Balu, N.J. and Lauby, M.G., 1994. *Power system stability and control* (Vol. 7). New York: McGraw-hill.
3. Padiyar, K.R., 1996. *Power system dynamics: stability and control*. New York: John Wiley.
4. Chakrabarti, A., 2013. *Power System Dynamics and Simulation*. PHI Learning Pvt. Ltd..
5. Vittal, V., McCalley, J.D., Anderson, P.M. and Fouad, A.A., 2019. *Power system control and stability*. John Wiley & Sons.

PS1211	ADVANCED POWER SYSTEM SIMULATION LABORATORY	L	T	P	C
		0	0	4	2

OBJECTIVES:

- To analyze the effect of FACTS controllers by performing steady state analysis.
- To have hands on experience on different wind energy conversion technologies

LIST OF EXPERIMENTS

1. Small-signal stability analysis of single machine-infinite bus system using classical machine model
2. Voltage stability analysis of single machine-infinite bus system
3. Induction motor starting analysis
4. Load flow analysis of two-bus system with STATCOM
5. Multi-objective optimization for economic dispatch in micro grid
6. Available Transfer Capability calculation using an existing load flow program
7. Simulation of variable speed wind energy conversion system- DFIG
8. Study of regional dispatch centre energy report
9. Computation of harmonic indices generated by a rectifier feeding a R-L load
10. Design of active filter for mitigating harmonics

11. Computation of Locational Marginal Pricing (LMP) in Restructured power systems

TOTAL: 60 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Analyze stability analysis on single machine and multi machine configuration.

CO2: Calculate Available Transfer Capacity and Locational marginal pricing for Deregulated power system.

CO3: Design active filter to mitigate and compute harmonic indices.

CO4: Demonstrate the operation of power system under dynamic conditions.

LIST OF EQUIPMENT FOR A BATCH OF 30 STUDENTS:

S. No.	Description of Equipment	Quantity Required
1.	Personal Computers (Intel Core i3, 250 GB, 1 GB RAM)	30
2.	Printer	1
3.	Server (Intel Core i3, 4 GB RAM) (High Speed Processor)	1
4.	Software: EMTP / ETAP / CYME / MIPOWER / Matlab/ any Power system simulation software	5 User Licenses
5.	Compilers: C / C++	30 users

PS1221 TECHNICAL PAPER WRITING AND PATENT FILING

L	T	P	C
1	0	2	2

OBJECTIVES:

- To impart knowledge and skills required for research
- To understand the problem formulation, analysis and solutions
- To familiarize in technical paper writing/presentation without violating professional ethics
- To give an idea about IPR, registration and its enforcement
- To give an knowledge about IPR Laws

UNIT I RESEARCH PROBLEM FORMULATION 3

Meaning of research problem- Sources of research problem, criteria characteristics of a good research problem, errors in selecting a research problem, scope and objectives of research problem.

UNIT II LITERATURE REVIEW 3

Importance of literature review in defining a problem, literature review, critical literature review, identifying gap areas from literature and research database. Use of tools / techniques for Research like Zotero/Mendeley, Software for paper formatting like LaTeX/MS Office, Software for detection of Plagiarism.

UNIT III TECHNICAL WRITING /PRESENTATION 3

Effective technical writing, how to write report, paper, developing a research proposal, format of research proposal, a presentation and assessment by a review committee.

UNIT IV INTRODUCTION TO INTELLUCTUAL PROPERTY RIGHTS 3

Introduction to IPRs, Basic concepts and need for Intellectual Property - Patents, Copyrights, Geographical Indications, IPR in India and Abroad –Patent Agents.

UNIT V REGISTRATION OF IPRs 3

Meaning and practical aspects of registration of Copy Rights, Trademarks, Patents, Geographical Indications, Patent Drafting.

TOTAL: 15+30=45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Construct problem formulation for a typical research work.

CO2: Examine the contribution of various researchers in the research topic identified.

CO3: Prepare an article / proposal based on research findings.

CO4: Outline the basic concepts involved in IPR and copyrights.

CO5: Describe the process of patent filing and registration.

REFERENCES:

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. *An introduction to Research Methodology.*
2. Kothari, C., 2017. *Research methodology methods and techniques,* New Age International (P) Ltd.,
3. Khanna, J.K., 1985. *Knowledge: Evolution, Structure & Research Methodology*. Ess Ess Publications.
4. Trochim, W.M., 2005. *Research methods: The concise knowledge base*. Atomic Dog Publishing.
5. Wadehra, B.L., 2006. *Law Relating to Patents, Trade Marks, Copyright Designs and Geographical Indications: Including Semiconductor Integrated Circuits and Layout-design; Protection of Plant Varieties & TRIPS*. Universal Law Publishing Company.
6. Sople, V.V., 2016. *Managing intellectual property: The strategic imperative*. PHI Learning Pvt. Ltd..
7. Satarkar, S.P., 2003. *Intellectual property rights and copyrights*. Ess Ess Publications.
8. Bouchoux, D.E., 2012. *Intellectual property: The law of trademarks, copyrights, patents, and trade secrets*. Cengage Learning.
9. Ganguli, P., 2001. *Intellectual Property Rights: Unleashing the Knowledge Economy*. Tata McGraw-Hill Publishing Company.
10. Frey, C.B., 2013. *Intellectual property rights and the financing of technological innovation: public policy and the efficiency of capital markets*. Edward Elgar Publishing.

PS1131	COMPUTER AIDED DESIGN OF ELECTRICAL APPARATUS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To learn the importance of computer aided design method.
- To familiarize with Finite Element Method as applicable for Electrical Engineering.
- To know the organization of a typical CAD package and MagNet software by practical simulation
- To design the DC series motor, Transformer and Squirrel cage Induction Motor using MagNet simulation software
- To apply CAD package for the design of different Power system apparatus.

UNIT I INTRODUCTION 9

Conventional design procedures - Limitations - Need for field analysis based design - Review of Basic principles of energy conversion - Development of Torque/Force – Review of Electromagnetic Field Equations

UNIT II PHILOSOPHY OF FEM 9

Mathematical models – Differential /Integral equations - Finite Difference method - Finite element method - Energy minimization - Variation method- 2D field problems - Discretization - Shape functions - Stiffness matrix - Solution techniques.

UNIT III BASICS OF MAGNET SOFTWARE AND ECAD PACKAGES 9

Introduction-Design of Object-Elements-Nodes-make component in a line-one dimension design of line,-two dimension design of Cylinder, rectangular, cube –three dimension design of fan, wheel, spanner-Elements of a ECAD System -Pre-processing - Modeling - Meshing - Material properties- Boundary Conditions - Setting up solution - Post processing

UNIT IV DESIGN APPLICATIONS IN ELECTRICAL MACHINES 9

Design of series DC motor: Wireframe model-solid model-Transient 2D with motion analysis - Design of core and shell type transformer: Wireframe model-solid model-static analysis - Design of Squirrel cage Induction Motor: Wireframe model-solid model-Transient 2D with motion analysis - Torque calculation in Switched Reluctance Motor.

UNIT V DESIGN APPLICATIONS IN POWER SYSTEM APPARATUS 9

Voltage Stress in Insulators - Capacitance calculation - Cable capacity - Design of Solenoid Actuator - Protective device coordination - Electrical substation grounding grid design.

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Explain the basics of design procedures and need for field analysis based design.

CO2: Explain the purpose of FEA and types of Finite Elements

CO3: Demonstrate the model of object, elements in 1D, 2D, 3D and types of solvers using MagNet software and ECAD Package

CO4: Design Electrical Machines using MagNet simulation software

CO5: Design electrical apparatus using ECAD Package with illustration to power system problems.

REFERENCES:

1. Salon, S.J., 1995. Computation of Losses, Resistance and Inductance. In *Finite Element Analysis of Electrical Machines* (pp. 75-95). Springer, Boston, MA.
2. Bianchi, N., 2005. *Electrical machine analysis using finite elements*. CRC press.
3. Bastos, J.P.A. and Sadowski, N., 2003. *Electromagnetic modeling by finite element methods*. CRC press.
4. Silvester, P.P. and Ferrari, R.L., 1996. *Finite elements for electrical engineers*. Cambridge university press.
5. Lowther, D.A. and Silvester, P.P., 2012. *Computer-aided design in magnetics*. Springer Science & Business Media.

PS1132	INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To impart knowledge on Motor Starting Studies.
- To understand the need for power factor correction and analyse the various methods that are used in the Power Factor Correction studies.
- To learn about the sources of harmonics, evaluate the harmonics present in the power system and mitigate them by filters.
- To analyse the sources that can cause the voltage flicker and find solutions to minimize the flicker.
- To impart knowledge on the ground grid analysis.

UNIT I MOTOR STARTING STUDIES 9

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

UNIT II POWER FACTOR CORRECTION STUDIES 9

Introduction - System Description and Modeling - Acceptance Criteria - Frequency Scan Analysis - Voltage Magnification Analysis - Sustained Overvoltages - 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 GROUND GRID ANALYSIS 9

Introduction - Acceptance Criteria - Ground Grid Calculations - Computer-Aided Analysis - Improving the Performance of the Grounding Grids - Conclusions.

TOTAL:45 PERIODS

OUTCOMES:

Upon completion of this course, Students will be able to

CO1: Illustrate the concept of motor starting methods using suitable simulation package.
CO2: Discuss the various studies involved in power factor correction.
CO3: Perform harmonic analysis and reduce the harmonics by using filters.
CO4: Elaborate on the flicker analysis by appropriate modeling of the load.
CO5: Design the appropriate ground grid for electrical safety.

REFERENCES:

1. Natarajan, R., 2002. *Computer-aided power system analysis*. CRC Press.

PS1133	NANO MATERIALS AND APPLICATIONS OF HIGH VOLTAGE ENGINEERING	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To enable the students to become familiar with different types
- To understand the various properties of nano materials.
- To impart knowledge on characterization methods of nano composites
- To impart knowledge on the awareness on electro-static hazards and safety measures
- To apply the Pulsed electric field technology in food processing and medical fields.

UNIT I INTRODUCTION TO NANO MATERIALS 9

Introduction to nano materials- Definition of nanocomposite, nanofillers, classification of nanofillers, carbon and non-carbon based nanofillers - Properties of nanomaterials- role of size in nanomaterials, nanoparticles, semiconducting nanoparticles, nanowires, nanoclusters, quantum wells, conductivity and enhanced catalytic activity in the macroscopic state

UNIT II PROPERTIES OF NANO MATERIALS 9

Nano composites and Properties- Metal-Metal nanocomposites, Polymer-Metal nanocomposites, Ceramic nanocomposites: Dielectric and CMR based nanocomposites. Mechanical Properties, Modulus and the Load-Carrying Capability of Nanofillers, Failure Stress and Strain Toughness, Glass Transition and Relaxation Behavior, Abrasion and Wear Resistance, Permeability, Dimensional Stability Contents, Thermal Stability and Flammability, Electrical and Optical Properties, Resistivity, Permittivity and Breakdown Strength, Refractive Index.

UNIT III NANOCOMPOSITES 9

Direct Mixing, Solution Mixing, Preparation and characterization of inorganic nanofillers - properties, synthesis, characterization and applications of SiO_2, TiO_2, ZrO_2, Al_2O_3 and CNT composite, Applications of nano filled materials for outdoor and indoor equipment.

UNIT IV SAFETY AND ELECTROSTATIC HAZARDS 9

Introduction – Nature of static electricity – Triboelectric series – Basic laws of Electrostatic electricity– materials and static electricity – Electrostatic discharges (ESD) – Static electricity problems – Hazards of Electrostatic electricity in industry – Hazards from electrical equipment and installations – Static eliminators and charge neutralizers – Lightning protection- safety measures and standards

UNIT V PULSED POWER APPLICATIONS 9

Introduction - Ion beam materials treatment -Air treatment and pollution control - Pulsed corona precipitators - Biological applications - Food processing: Processing of juices, milk, egg, meat and fish-Water purification Medical applications -Ultra wideband and HPM applications - X-ray simulators.

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Outline the structure of nano material.

CO2: Comprehend the characteristics of nano materials.

CO3: Demonstrate the processing methods of nano composite and applications.

CO4: Describe the various safety measures against electrostatic hazards.

CO5: Summarize the pulsed power applications in food processing and medical fields.

REFERENCES:

1. Haddad, A., Haddad, M., Warne, D.F. and Warne, D. eds., 2004. *Advances in high voltage engineering* (Vol. 40). IET.
2. Shea, J.J., 1998. Electrical Insulation in Power Systems. *IEEE Electrical Insulation Magazine*, *14*(4), pp.42-42.
3. Khalifa, M., 1990. High-voltage engineering.
4. Barbosa-Cánovas, G.V. and Zhang, Q.H. eds., 2019. *Pulsed electric fields in food processing: fundamental aspects and applications*. CRC Press.
5. Lelieveld, H.L., Notermans, S. and De Haan, S.W.H. eds., 2007. *Food preservation by pulsed electric fields: from research to application*. Elsevier.
6. Wiederrecht, G., 2010. *Handbook of nanofabrication*. Academic Press.
7. Ajayan, P.M., 2003. Bulk metal and ceramics nanocomposites. *Nanocomposite science and technology*, pp.1-76.
8. Altavilla, C. and Ciliberto, E. eds., 2017. *Inorganic nanoparticles: synthesis, applications, and perspectives*. CRC Press.
9. Mai, Y.W. and Yu, Z.Z., 2006. *Polymer nanocomposites*. Woodhead publishing.

PS1134	POWER SYSTEM PLANNING AND RELIABILITY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To introduces the objectives of Load forecasting.
- To study the fundamentals of Generation system, transmission system and Distribution system reliability analysis
- To illustrate the basic concepts of Expansion planning

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 AI in load forecasting.

UNIT II EXPANSION PLANNING 9

Basic concepts on expansion planning-procedure followed for integrate transmission system planning, current practice in India-Capacitor placer problem in transmission system and radial distributions system.

UNIT III GENERATION SYSTEM RELIABILITY ANALYSIS 9

Probabilistic generating Units models: Mathematical, Probability density function, generating unit model - Probabilistic load models: Load Probability distribution, Modeling forecast uncertainty, Expected value of demand and energy - Determination of reliability of isolated system and interconnected generation systems

UNIT IV TRANSMISSION SYSTEM RELIABILITY ANALYSIS 9

Deterministic contingency analysis: Dc Power Flow Contingency Analysis, A Z Matrix method for contingency analysis, - Probabilistic transmission system reliability analysis- Capacity state classification by subsets - Determination of reliability indices like LOLP and expected value of demand not served.

UNIT V EVALUATION OF RELIABILITY WORTH 9

Introduction – Implicit 'explicit evaluation of reliability worth - Customer interruption cost evaluation - Basic evaluation approaches - Cost of interruption surveys: Considerations, Cost valuation methods - Customer damage functions: Concepts, Reliability worth assessment at HLI, Reliability worth assessment at HLII, Reliability worth assessment in the distribution functional zon, Station reliability worth assessment.

TOTAL:45 PERIODS

OUTCOMES:

Upon completion of this course, Students will be able to

- CO1: Apply the concept and methods for load forecasting in power system.
- CO2: Analyze expansion planning of Isolated and interconnected systems.
- CO3: Describe the concepts of Contingency analysis and Probabilistic Load flow Analysis.
- CO4: Analyze the concepts of Expansion planning.
- CO5: Explain the fundamental concepts of evaluation of reliability worth in distribution systems.

REFERENCES:

1. Sullivan, R.L., 1977. Power system planning.
2. Wang, X. and McDonald, J.R., 1994. *Modern power system planning*. McGraw-Hill Companies.
3. Billinton, R. and Allan, R.N., 1996. Evaluation of reliability worth. In *Reliability Evaluation of Power Systems* (pp. 443-475). Springer, Boston, MA.

PS1135	POWER SYSTEM VOLTAGE STABILITY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To introduce the time frames of power system stability.
- To learn about the maximum deliverable power.

- To learn about the voltage dependence of loads.
- To discuss about the PV, PQ and PVQ curves.
- To learn about the exposure in Static voltage stability methods.

UNIT I INTRODUCTION 9

Power system stability classification – Basic concepts related to Voltage stability- physical phenomenon of voltage collapse – Voltage stability analysis- Dynamic and static analysis- Prevention of Voltage collapse-time frames for voltage instability, mechanisms – maintaining viable voltage levels- Introduction to standards.

UNIT II TRANSMISSION SYSTEM ASPECTS 9

Single load infinite bus system – maximum deliverable power – lossless transmission – maximum power – power voltage relationships – generator reactive power requirement – instability mechanism- Effect of compensation-Line series compensation – shunt compensation - static VAR compensator –VQ curves – effect of adjustable transformer ratio.

UNIT III GENERATION ASPECTS 9

A review of Synchronous machine theory – Frequency and voltage controllers - Limiting devices affecting voltage stability – over excitation limiters – description –field current, armature current limiters – P and Q Expressions- capability curves.

UNIT IV LOAD ASPECTS 9

Voltage dependence of loads – load characteristics – exponential load – polynomial load- Saddle node bifurcation – simple power system example (statics) – simple power system example (dynamics).

UNITV STATIC VOLTAGE STABILITY METHODS 9

Continuation power flow methods, PV analysis, VQ analysis, Time domain analysis, modal analysis – Voltage stability analysis of simple power system using simulation tools.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Classify and explain the time frames of power system stability.
CO2: Explain maximum deliverable power and generator reactive power requirements.
CO3: Describe the voltage dependence of loads and capability curves in transmission systems.
CO4: Demonstrate PV, PQ and PVQ curves with suitable examples.
CO5: Apply Continuation power flow for voltage stability assessment.

REFERENCES:

1. Van Cutsem, T. and Vournas, C., 2007. *Voltage stability of electric power systems*. Springer Science & Business Media.
2. Balu, C.W.T.N.J. and Maratukulam, D., 1994. *Power system voltage stability*. McGraw Hill.
3. Kundur, P., Balu, N.J. and Lauby, M.G., 1994. *Power system stability and control* (Vol. 7). New York: McGraw-hill.
4. Assessment, V.S., 2002. Concepts, practices and tools. *IEEE/PES Power System Stability Subcommittee Special Publication*.

PS1136 SOLAR AND ENERGY STORAGE SYSTEMS

	L	**T**	**P**	**C**
	3	**0**	**0**	**3**

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

UNIT I INTRODUCTION 9

Characteristics of sunlight – semiconductors and P-N junctions –behavior of solar cells – cell properties – PV cell interconnection, modeling of PV cells, Partial Shading in PV, Bypass Diode and Blocking Diode Application.

UNIT II STAND ALONE PV SYSTEM 9

Solar modules – storage systems – power conditioning and regulation – MPPT (P&O and IC Methods) - protection – standalone PV systems design – sizing of solar system for 5 HP motor pump.

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, fuel cells, ultra capacitor and compressed air technologies.

UNIT V APPLICATIONS 9

Water pumping – battery chargers – solar car – direct-drive applications –Space – Telecommunications, Simulation of PV systems.

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Illustrate the concept of modelling and analysis of PV cells
CO2: Design the standalone PV system for a typical application
CO3: Describe the design issues in grid connected PV system.
CO4: Explain about the modeling of different energy storage systems and their performances
CO5: Design PV system for various application such as water pumping, battery chargers, solar car, direct-drive applications, space & telecommunications

REFERENCES:

1. Solanki, C.S., 2015. *Solar photovoltaics: fundamentals, technologies and applications*. PHI Learning Pvt. Ltd..
2. Wenham, S.R., 2011. *Applied photovoltaics*. Routledge.
3. Lorenzo, E., 1994. *Solar electricity: engineering of photovoltaic systems*. Earthscan/James & James.
4. Barnes, F.S. and Levine, J.G. eds., 2011. *Large energy storage systems handbook*. CRC press.

5. McNeils, Frenkel, Desai, 1990. *Solar & Wind Energy Technologies*, Wiley Eastern.
6. Sukhatme, S.P. and Nayak, J.K., 2017. *Solar energy*. McGraw-Hill Education.

PS1231	AI TECHNIQUES FOR POWER SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To provide insight into fundamentals of Artificial Intelligence Techniques.
- To expose the students to use appropriate ANN framework for solving power system problems.
- To teach about the concept of fuzziness involved in various systems.
- To expose the ideas about genetic algorithm
- To convey application of Artificial Intelligence techniques in power system.

UNIT I INTRODUCTION 9

Introduction -Approaches to intelligent control - Architecture for intelligent control - Symbolic reasoning system – Rule based systems - AI approach - Knowledge representation - Expert systems.

UNIT II ARTIFICIAL NEURAL NETWORKS 9

Concept of Artificial Neural Networks and its basic mathematical model - McCulloch-Pitts neuron model - simple perceptron - Feed-forward Multilayer Perceptron – Learning and Training the neural network - Hopfield network - Self-organizing network and Recurrent network- Neural Network based controller to enhance power systems protection.

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 (MPPT controller – Solar PV 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 (Simple Case Studies)

UNIT V APPLICATION OF AI IN POWER SYSTEMS 9

Load forecasting using ANN – Economic load dispatch (Single Objective and Multi objective using GA) – Unit Commitment using Genetic algorithm - Load frequency of Single Area and Two Area Power System using Fuzzy Controller

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Describe the concepts of Artificial Intelligence and their role in optimization.

CO2: Explain the architecture of different types of ANN models.

CO3: Illustrate the concept of fuzzy logic system and its application in modeling & control of nonlinear systems.

CO4: Apply Genetic Algorithm for solving single & multi objective optimization problem.

CO5: Apply various AI techniques (ANN, Fuzzy Logic and GA) for various application in power systems such as load forecasting, unit commitment etc.

REFERENCES:

1. Rajasekaran, S. and Pai, G.V., 2003. *Neural networks, fuzzy logic and genetic algorithm: synthesis and applications (with cd)*. PHI Learning Pvt. Ltd..
2. Sivanandam, S.N. and Deepa, S.N., 2007. *Principles of soft computing (with CD)*. John Wiley & Sons.
3. Padhy, N.P., 2005. *Artificial intelligence and intelligent systems*. Oxford University Press.
4. Chakraverty, S., Sahoo, D.M. and Mahato, N.R., 2019. *Concepts of soft computing: fuzzy and ANN with programming*. Springer.

PS1232	DISTRIBUTED GENERATION AND MICROGRID	L	T	P	C
		3	0	0	3

OBJECTIVES:

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

UNIT I INTRODUCTION 9

Conventional power generation: advantages and disadvantages, Energy crises, Nonconventional 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, Types of DGs, 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 microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids

UNIT V CONTROL AND OPERATION OF MICROGRID 9

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

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Describe various schemes of conventional and nonconventional power generation

CO2: Explain the topologies and energy sources of distributed generation.

CO3: Elucidate the requirements for grid interconnection and its impact with NCE sources.

CO4: Describe the fundamental concept of Microgrid and its configuration.

CO5: Outline the control and operation of Microgrid system.

REFERENCES:

1. Chauhan, R.K. and Chauhan, K. eds., 2019. *Distributed Energy Resources in Microgrids: Integration, Challenges and Optimization*. Academic Press.
2. Yazdani, A. and Iravani, R., 2010. *Voltage-sourced converters in power systems: modeling, control, and applications*. John Wiley & Sons.
3. Neacsu, D.O., 2014. *Power-switching converters: medium and high power*. CRC press.
4. Solanki, C.S., 2015. *Solar photovoltaics: fundamentals, technologies and applications*. PHI Learning Pvt. Ltd..
5. Manwell, J.F., McGowan, J.G. and Rogers, A.L., 2010. *Wind energy explained: theory, design and application*. John Wiley & Sons.
6. Hall, D.O. and Overend, R.P., 1987. *Biomass: regenerable energy*.
7. Twidell, J. and Weir, T., 2015. *Renewable energy resources*. Routledge.

PS1233	ELECTRIC VEHICLES AND POWER MANAGEMENT	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To understand the concept of electrical vehicles and its operations
- To understand the need for energy storage in hybrid vehicles
- To provide knowledge about various possible energy storage technologies that can be used in electric vehicles

UNIT I ELECTRIC VEHICLES AND VEHICLE MECHANICS 9

Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Engine ratings, Comparisons of EV with internal combustion Engine vehicles, Fundamentals of vehicle mechanics.

UNIT II ARCHITECTURE OF EV's AND POWER TRAIN COMPONENTS 9

Architecture of EV's and HEV's – Plug-n Hybrid Electric Vehicles (PHEV)- Power train components and sizing, Gears, Clutches, Transmission and Brakes.

UNIT III ELECTRIC PROPULSION SYSTEMS 9

DC/DC chopper based four quadrant operations of DC drives – Inverter based V/f Operation (motoring and braking) of induction motor drive system – Induction motor based vector control operation – Switched reluctance motor (SRM) drives, BLDC drives.

UNIT IV BATTERY ENERGY STORAGE SYSTEM 9

Battery Basics, Different types, Battery Parameters, Battery modeling, Traction Batteries, Battery Management system for Lithium ion Batteries.

UNIT V ALTERNATIVE ENERGY STORAGE SYSTEMS 9

Fuel cell – Characteristics- Types – hydrogen Storage Systems and Fuel cell EV – Ultra capacitors

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: understand the operation of Electric vehicles
CO2: outline the concept of EVs, HEVs and PHEVs
CO3: describe the operating principle of various electric propulsion systems
CO4: explain the various energy storage technologies for electrical vehicles
CO5: describe the various alternate energy storage systems for electrical vehicles

REFERENCES:

1. Husain, I., 2011. *Electric and hybrid vehicles: design fundamentals*. CRC press.
2. Ali Emadi, Mehrdad Ehsani, John M.Miller, 2010. *Vehicular Electric Power Systems*. Special Indian Edition, Marcel Dekker, Inc..
3. Ehsani, M., Gao, Y., Longo, S. and Ebrahimi, K., 2018. *Modern electric, hybrid electric, and fuel cell vehicles.* CRC press.

PS1234	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 acquire knowledge in the field of energy management and auditing process.

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 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 - Paralleling of current transformers - Instrument transformer burdens-Multitasking solid-state meters – Metering location vs. requirements- Metering techniques and practical examples.

UNIT V ENERGY AUDIT 9

Definition, Energy audit- need, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments - Bureau of Energy Efficiency (the manner and intervals of time for conduct of energy audit) Regulations,2008.

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Describe the need for energy management and auditing process

CO2: Outline the basic concepts of economic analysis and load management in utility system.

CO3: Deduce the energy management strategy on various electrical equipments.

CO4: Interpret the concepts of metering and factors influencing cost function

CO5: Illustrate the process of energy management and auditing.

REFERENCES:

1. Capehart, B.L., Turner, W.C. and Kennedy, W.J., 2006. *Guide to energy management*. The Fairmont Press, Inc..
2. Eastop, T.D. and Croft, D.R., 1990. *Energy efficiency for engineers*.
3. Reay D.A, 1977. *Industrial Energy Conservation*, 1st edition, Pergamon Press.
4. Tyagi, A.K. ed., 2003. *Handbook on energy audits and management*. Teri.
5. *IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities*, in IEEE Std. 739-1995 [The Bronze Book], vol., no., pp.1-372, 18 Nov. 1996.

PS1235	FLEXIBLE AC TRANSMISSION SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To emphasis the need for FACTS and its controllers..
- To learn the characteristics, modelling and design of Static VAR Compensator and its applications
- To have an in-depth knowledge on the operation, modelling and control of TCSC and GCSC and its applications
- To learn basic concepts, modelling and design of Voltage Source Converter based FACTS Controllers and its applications
- To analyze the interaction of different FACTS controller and perform control coordination.

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 of TCSC-GCSC – Modelling of TCSC and GCSC for load flow studies- modeling TCSC and GCSC for stability studied- Applications of TCSC and GCSC - Distributed FACTS Device

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 CO-ORDINATION 9

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

TOTAL: 45 PERIODS

OUTCOMES:

Students will be able to

CO1: Explain the basics of power transmission networks, need and types of FACTS

CO2: Design Static VAR Compensator for various contingency applications.

CO3: Model and control TCSC and GCSC in ac transmission systems.

CO4: Model Voltage Based Control for series and shunt compensation devices.

CO5: Describe the interaction of different FACTS controllers and its control coordination.

REFERENCES:

1. Mathur, R.M. and Varma, R.K., 2002. *Thyristor-based FACTS controllers for electrical transmission systems*. John Wiley & Sons.
2. Hingorani, N.G., 1999. LaszloGyugyi, Understanding Facts: Concepts and Technology of Flexible AC Transmission Systems, *Wiley-IEEE Press*.
3. Sood, V.K., 2006. *HVDC and FACTS controllers: applications of static converters in power systems*. Springer Science & Business Media.
4. John A.T. 1999. *Flexible AC Transmission System*, Institution of Electrical and Electronic Engineers (IEEE).

PS1236	WIND ENERGY CONVERSION SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To learn about the basic concepts of wind energy conversion system
- To learn the design and control principles of Wind turbine.
- To understand the concepts of fixed speed wind energy conversion systems.
- To understand the concepts of Variable speed wind energy conversion systems.
- To analyze the grid integration issues.

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 modelling - 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

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Review the basic concepts of wind energy conversion system.
CO2: Outline the mathematical modeling and control of the wind turbine.
CO3: Discuss the design of fixed speed system.
CO4: Explain the need of variable speed system and its modeling.
CO5: Summarize the grid integration issues and current practices of wind interconnections with power system.

REFERENCES:

1. John, W. and Nicholas, J., 1997. Wind energy technology. *New York: John Wiley and Sons Inc.*.
2. Heir, S., 1998. *Grid Integration of WECS*.
3. Freris, L.L. and Freris, L.L. eds., 1990. *Wind energy conversion systems* (Vol. 31). New York: Prentice Hall.
4. Bhadra, S.N, Kastha,D, Banerjee,S. 2010. *Wind Electrical Systems*, Oxford University Press.
5. Ion Boldea, 2006. *Variable speed generators*, Taylor & Francis group.
6. Golding, E.W. and Harris, R.I., 1976. *The generation of electricity by wind power*. London: E. & FN Spon.

PS1331	ELECTROMAGNETIC FIELD COMPUTATION AND MODELLING	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To refresh the fundamentals of Electromagnetic Field Theory
- To provide foundation in formulation and computation of Electromagnetic Fields using analytical and numerical methods.
- To impart knowledge in fundamentals of FEM
- To compute and analyze the field quantities using FEM
- To formulate, solve, analyze and optimize the design of electrical components

UNIT I INTRODUCTION 9

Review of basic field theory – Electric Dipole - Electric fields in material space- Maxwell's equations – Constitutive relationships and Continuity equations – Laplace, Poisson and Helmholtz equation – principle of energy conversion – force/torque calculation

UNIT II BASIC SOLUTION METHODS FOR FIELD EQUATIONS 9

Limitations of the conventional design procedure, need for the field analysis based design, problem definition, boundary conditions, solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods- Finite Difference Method

UNIT III FORMULATION OF FINITE ELEMENT METHOD (FEM) 9

Introduction to FEM - Variational Formulation – Energy minimization – Discretisation – Shape functions –Stiffness matrix –1D and 2D planar and axial symmetry problems.

UNIT IV COMPUTATION OF BASIC QUANTITIES USING FEM PACKAGES 9

Basic quantities – Energy stored in Electric Field – Capacitance – Magnetic Field – Linked Flux – Inductance – Force – Torque – Skin effect – Resistance

UNIT V DESIGN APPLICATIONS 9

Design of Insulators –Bushings- Magnetic actuators – Transformers – Rotating machines.

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Explain the basic underlying principles of electromagnetic theory.
CO2: Compute Electromagnetic Fields from Maxwell's equations.
CO3: Formulate FEM problems from the fundamental concepts.
CO4: Compute the respective field using FEM (post processing)
CO5: Optimize the design of electrical power equipment.

REFERENCES:

1. Sadiku, M.N., 2014. *Elements of electromagnetics*. Oxford university press.
2. Binns, K.J., Trowbridge, C.W. and Lawrenson, P.J., 1992. *The analytical and numerical solution of electric and magnetic fields*. Wiley.
3. Bianchi, N., 2005. *Electrical machine analysis using finite elements*. CRC press.
4. Ida, N. and Bastos, J.P., 2013. *Electromagnetics and calculation of fields*. Springer Science & Business Media.
5. Salon, S.J., 1995. *Finite element analysis of electrical machines* (Vol. 101). Boston: Kluwer academic publishers.
6. Silvester, P.P. and Ferrari, R.L., 1996. *Finite elements for electrical engineers*. Cambridge university press.
7. Hayt Jr, W.H., Buck, J.A. and Akhtar, M.J., 2020. *Engineering Electromagnetics (SIE)*. McGraw-Hill Education.

PS1332	**POWER QUALITY ASSESSMENT AND MITIGATION**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

OBJECTIVES:

- To provide knowledge about various power quality issues.
- To understand the concept of power and power factor in single phase and three phase
- Systems supplying nonlinear loads.
- To equip with required skills to design conventional compensation techniques for power factor correction and load voltage regulation.
- To introduce the control techniques for the active compensation.
- To understand issues in smart grids and mitigation techniques using custom power devices such as DVR & UPQC

UNIT I INTRODUCTION 9

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

UNIT II ANALYSIS OF SINGLE PHASE AND THREE PHASE SYSTEM 9

Single phase linear and nonlinear loads –single phase sinusoidal, non-sinusoidal source – supplying linear and nonlinear load – three phase Balance system – three phase unbalanced system – three phase unbalanced and distorted source supplying nonlinear loads – concept of Power factor – three phase three wire – three phase four wire system.

UNIT III CONVENTIONAL LOAD COMPENSATION METHODS 9

Principle of load compensation and voltage regulation – classical load balancing problem: open loop balancing – closed loop balancing, current balancing – harmonic reduction and voltage sag reduction– analysis of unbalance – instantaneous of real and reactive powers – Extraction of Fundamental sequence component from measured.

UNIT IV SHUNT COMPENSATION USING DSTATCOM 9

Compensating single – phase loads – Ideal three phase shunt compensator structure – generating reference currents using instantaneous PQ theory – Instantaneous symmetrical components theory – Generating reference currents when the source is unbalanced –Realization and control of DSTATCOM – DSTATCOM in Voltage control mode

UNIT V POWER QUALITY ISSUES IN SMART GRID AND ITS MITIGATION TECHNIQUES 9

Power quality management (voltage dips, harmonics, flickers, and reactive power control) - Frequency management - Influence of WECS on system transient response - Interconnection standards and grid code requirements for integration. Rectifier supported DVR – DC Capacitor supported DVR – DVR Structure – voltage Restoration – Series Active Filter – Unified power quality conditioner.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Describe the consequences of various power quality issues.

CO2: Demonstrate harmonic analysis of single phase and three phase systems supplying Nonlinear loads.

CO3: Describe about load compensation and the problems associated with them.

CO4: Explain shunt Compensation methods using DSTATCOM .

CO5: Explain the mitigation techniques using custom power devices such as DSTATCOM, DVR & UPQC

REFERENCES:

1. Ghosh, A. and Ledwich, G., 2012. *Power quality enhancement using custom power devices*. Springer science & business media.
2. Heydt, G.T., 1991. *Electric power quality*. Stars in a circle publications.
3. Dugan, R.C., McGranaghan, M.F. and Beaty, H.W., 1996. *Electrical power systems quality*.

PS1333	POWER SYSTEM OPTIMIZATION	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To understand the classification of optimization
- To study the linear programming models and solution techniques
- To study the different non-linear programming problem solution techniques
- To understand the concept of dynamic programming
- To study the fundamentals genetic algorithm and it applications

UNIT I OPTIMIZATION TECHNIQUES – CLASSICAL AND MODERN 9

Definition, Classification of optimization problems, Classical and Swarm Optimization Techniques, Lagrangian method, penalty function method, dynamic programming – Multi objective optimization. Introduction to Genetic Algorithm, Particle Swarm Optimization

UNIT II OPTIMAL GENERATION SCHEDULING OF THERMAL PLANTS 9

Introduction-Generator operating cost- Economic Dispatch (ED) problem - constraints -Optimal generation scheduling-Newton Raphson method. Transmission loss coefficients-exact loss formula-incremental transmission loss. ED based on penalty factors.

UNIT III OPTIMAL HYDROTHERMAL SCHEDULING 9

Introduction – Short range hydrothermal scheduling – Model - transmission losses– Solution using Newton Raphson method – Hydro plant modelling for long term operation-Pumped storage plants-Long range generation scheduling

UNIT IV MULTI OBJECTIVE GENERATION SCHEDULING 9

Introduction – Multi objective optimisation methods –Multi objective thermal dispatch problem- ε Constraint method- Multi objective dispatch for active and reactive power balance.

UNIT V STOCHASTIC MULTI OBJECTIVE GENERATION SCHEDULING 9

Introduction- Multi objective stochastic optimal thermal power dispatch -Stochastic economic emission load dispatch-Problem formulation-Solution approach.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Classify the various optimization problems and techniques.
CO2: To interpret the optimization techniques for Thermal Plants.
CO3: To model and schedule the hydro0thermal operation.
CO4: To apply multi-objective optimization for various power system problems.
CO5: To solve stochastic multi-objective optimization for various power system problems.

REFERENCES:

1. Rao, S.S., 2019. *Engineering optimization: theory and practice*. John Wiley & Sons.
2. Deb, K., 2001. Multi-objective optimization using evolutionary algorithms (Vol. 16). John Wiley & Sons.
3. Kothari, D.P. and Dhillon, J.S., 2004. Power System Optimization, PHI Learning Pvt.
4. Polak, E., 1971. *Computational methods in optimization: a unified approach* (Vol. 77). Academic press.

PS1334	POWER SYSTEM STATE ESTIMATION	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To introduce the state estimation on DC network.
- To impart in-depth knowledge on power system state estimation.
- To get insight of network observability

- To gain knowledge on bad data deduction and identification.
- To understand PMUs and their use in State Estimation

UNIT I INTRODUCTION TO STATE ESTIMATION 9

Need for state estimation – Measurements – Noise - Measurement functions – Measurement Jacobian – Weights - Gain matrix - State estimation as applied to DC networks - Comparison of Power flow and State Estimation problems - Energy Management System .

UNIT II WEIGHTED LEAST SQUARE ESTIMATION 9

Building network models - Maximum likelihood estimation - Measurement model and assumptions - WLS State Estimation Algorithm - Measurement functions - Measurement Jacobian matrix - Gain matrix - Cholesky decomposition and performing forward and backward substitutions - Decoupled formulation of WLS State estimation - DC State estimation model

UNIT III NETWORK OBSERVABILITY ANALYSIS 9

Network and graphs, Network matrices, loop equations, Methods Observability analysis, Numerical Method based on Nodal Variable formulation and branch variable formulation, Topological Observability analysis, Determination of critical measurements

UNIT IV BAD DATA DETECTION AND IDENTIFICATION 9

Properties of measurement residuals - Classification of measurements - Bad data detection and identification using Chi-squares distribution and normalized residuals - Bad data identification - Largest normalized residual test and Hypothesis testing identification - Bad data detection using PMU.

UNIT V PHASOR MEASUREMENT UNITS 9

Basics of Phasor Measurement Unit (PMU) - Optimal placement of PMUs - Methods to reduce the number of PMUs. State estimation including PMU - Optimal placement of PMUs in large scale systems - State estimation including FACTS devices.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Explain the need for state estimation and its measurement.
CO2: Apply suitable techniques for state estimation model.
CO3: Illustrate the concept of network observability.
CO4: Demonstrate the principle of bad date detection and identification.
CO5: Describe the basic of PMU's and methods for its optimal placement.

REFERENCES:

1. Abur, A. and Exposito, A.G., 2004. *Power system state estimation: theory and implementation*. CRC press.
2. Monticelli, A., 2012. *State estimation in electric power systems: a generalized approach*. Springer Science & Business Media.
3. Mukhtar Ahmad, 2013. *Power System State Estimation*", Lap Lambert Acad Publishers.
4. Naim Logic, 2010. *Power System State Estimation*, LAP Lambert Acad. Publ.
5. Chernousko, F.L., 1993. *State estimation for dynamic systems*. CRC Press.

PS1335	SCADA AND DCS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To understand the basic concepts and components of SCADA
- To introduce the SCADA communication protocols
- To apply the SCADA technology to power systems for automation
- To emphasis the role of SCADA monitoring and control concepts.
- To give an overview of DCS used in industry.

UNIT I INTRODUCTION TO SCADA 9

SCADA overview, general features, SCADA architecture, SCADA Applications, Benefits, Remote Terminal Unit (RTU), Human- Machine Interface Units (HMI), Display Monitors/Data Logger Systems, Intelligent Electronic Devices (IED), Communication Network, SCADA Server, SCADA Control systems and Control panels.

UNIT II SCADA COMMUNICATION 9

SCADA Communication requirements, Communication protocols: Past, Present and Future, Structure of a SCADA Communications Protocol, Comparison of various communication protocols- IEC61850 based communication architecture, Communication media like Fiber optic, PLCC etc. Interface provisions and communication extensions, synchronization with NCC, DCC, IOT, Cyber cell, Redundancy of Network.

UNIT III SCADA IN POWER SYSTEM AUTOMATION 9

Applications in Generation, Transmission and Distribution sector, Substation SCADA system Functional description, System specification, System selection such as Substation configuration, IEC61850 ring configuration, SAS cubicle concepts, gateway interoperability list, signal naming concept. System Installation, Testing and Commissioning.

CASE STUDIES: SCADA Design for 132/66/11kV of any utility Substation and IEC 61850 based SCADA Implementation issues in utility Substations.

UNIT IV SCADA MONITORING AND CONTROL 9

Online monitoring the event and alarm system, trends and reports, Blocking list, Event disturbance recording. Control function: Station control, bay control, breaker control and disconnector control.

UNIT V DISTRIBUTED CONTROL SYSTEM 9

DCS: Evolution & types – Hardware architecture – Field control station – Interfacing of conventional and smart field devices (HART and FF enabled) with DCS Controller – Communication modules – Operator and Engineering Human interface stations – Study of any one DCS available in market..

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Interpret the SCADA system components and its significance.

CO2: Describe the need and advantages of communication protocols for SCADA.

CO3: Identify the applications of SCADA in the Power System Automation.
CO4: Express the need and importance of monitoring and control logic for SCADA based power systems.
CO5: Describe the DCS evolution, architecture and its important components.

REFERENCES:

1. Boyer, S.A., 2009. *SCADA: supervisory control and data acquisition*. International Society of Automation.
2. Clarke, G., Reynders, D. and Wright, E., 2004. *Practical modern SCADA protocols: DNP3, 60870.5 and related systems*. Newnes.
3. Shaw, W.T., 2006. *Cybersecurity for SCADA systems*. Pennwell books..
4. Bailey, D. and Wright, E., 2003. *Practical SCADA for industry*. Elsevier.
5. Wiebe, M., 1999. *A Guide to Utility Automation: AMR, SCADA, and IT Systems*. Pennwell Books.
6. Dieter K. Hammer, Lonnie R. Welch, Dieter K. Hammer, 2001. *Engineering of Distributed Control Systems,* 1st Edition, Nova Science Publishers, USA.
7. Lukas, M.P., 1986. *Distributed control systems: their evaluation and design*. John Wiley & Sons, Inc..

PS1336	**SMART GRID TECHNOLOGIES**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

OBJECTIVES:

- To understand concept of smart grid and its advantages over conventional grid
- To know smart metering techniques
- To learn wide area measurement techniques
- To understand the problems associated with integration of distributed generation & its solution through smart grid.
- To familiarize the high performance computing for Smart Grid Applications

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 (TRANSMISSION) 9

Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control.

UNIT III SMART GRID TECHNOLOGIES (DISTRIBUTION) 9

DMS, Volt/VAr control, Fault Detection, Isolation and service restoration, Outage management, High- Efficiency Distribution Transformers, Phase Shifting Transformers, and Plug in Hybrid Electric Vehicles (PHEV).

UNIT IV 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): RTUs, GPS synchronization,, Intelligent Electronic Devices (IED) & their application for monitoring & protection, Microgrid and smart grid comparison.

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, Computing algorithms for Smart grid, IOT, Cyber Security for Smart Grid.

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Interpret the concepts of smart grid and its present developments.

CO2: Discuss about different transmission technologies in smart grid.

CO3: Discuss about different distribution technologies in smart grid.

CO4: Explain smart meters and advanced metering infrastructure devices.

CO5: Articulate on LAN, WAN and cloud computing for smart grid applications.

REFERENCES:

1. Borlase, S. ed., 2016. *Smart grids: infrastructure, technology, and solutions*. CRC press.
2. Ekanayake, J.B., Jenkins, N., Liyanage, K., Wu, J. and Yokoyama, A., 2012. *Smart grid: technology and applications*. John Wiley & Sons.
3. Gungor, V.C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C. and Hancke, G.P., 2011. Smart grid technologies: Communication technologies and standards. *IEEE transactions on Industrial informatics*, *7*(4), pp.529-539.
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.

PS1337	APPLICATION OF POWER ELECTRONICS IN POWER SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To provide the mathematical fundamentals necessary for deep understanding of Power Converter operating modes.
- To provide the electrical circuit concepts behind the different working modes of Power Converters so as to enable deep understanding of their operation.
- To provide required skills to formulate and design inverters for generic load and for machine Loads.
- To equip with required skills to derive the criteria for the design of power converters starting from basic fundamentals.
- To analyze and comprehend the various operating modes of different configurations of power Converters
- To know the various applications of power electronics in power system and its simulation outputs.

UNIT I AC-DC CONVERTERS 9

Single Phase AC - DC Converter, Three Phase AC - DC Converter, continuous and discontinuous conduction mode, Simulation of AC - DC Converter, Applications: EV Charging and HVDC Transmission.

UNIT II DC-AC CONVERTERS 9

Single Phase DC - AC Converter, Three Phase DC - AC Converter, PWM Techniques, Space Vector Modulation Techniques, Simulation of DC - AC Converter, Applications: Solar PV Systems and FACTS.

UNIT III AC – DC – AC CONVERTERS 9

Introduction to AC-DC-AC Converter, Principle of operation of single phase and Three Phase AC-DC-AC Converter, Simulation of AC - DC - AC Converter, Applications: Wind Energy Systems and Power Conditioners.

UNIT IV DC to DC CONVERTERS 9

DC Choppers, Types of DC Choppers, Control Strategies of chopper, Principle of operation of BOOST Converter, BUCK Converter, BUCK-BOOST Converter and SEPIC Converter, Simulation of DC Choppers, Applications: Solar PV MPPT, EV Battery Management Systems.

UNIT V MODERN POWER CONVERTERS 9

Multilevel concept – diode clamped – flying capacitor – cascaded type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters, Matrix Converters, Cuk converter, Luo converter, Voltage-Fed Z-source inverters.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Describe the operation of various AC-DC converter.
CO2: Demonstrate the various PWM techniques in inverter.
CO3: Summarize the working principle and applications of AC-DC-AC converter.
CO4: Interpret the concept of various DC-DC converters.
CO5: Explain the various modern power converters for electrical power system.

REFERENCES:

1. Rashid, M.H., 2004. Power Electronics Circuits, Devices, and Applications 3'd Edition.
2. Jai P. Agrawal, 2002. *Power Electronics Systems*, 2nd Edition, Pearson Education.
3. Bose, B.K., 2002. *Modern power electronics and AC drives* (Vol. 123). Upper Saddle River, NJ: Prentice hall.
4. Undeland, M.N., Robbins, W.P. and Mohan, N., 1995. Power electronics. In *Converters, Applications, and Design*. John Wiley & Sons.
5. Philip T. krein, 1998. *Elements of Power Electronics,* Oxford University Press.
6. Sen, P.C., 2005. *Modern power electronics*. S. Chand Publishing.
7. Bimbhra, D.P., 2003. *Power Electronics,* 11th Edition, Khanna Publishers.
8. Wu, B. and Narimani, M., 2017. *High-power converters and AC drives*. John Wiley & Sons.
9. Hart, D.W., 2011. *Power electronics*. Tata McGraw-Hill Education.

PS1338	CONTROL AND PROTECTION OF MICROGRID	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To familiarize the power quality management issues in microgrid.
- To study the concepts behind economic analysis and Load management.
- To illustrate the concept of distributed generation
- To analyze the impact of grid integration.
- To study concept of microgrid and its configuration

UNIT I DISTRIBUTED ENERGYRE SOURCES 9

Introduction - Combined heat and power (CHP) systems - Micro-CHP systems - Wind energy conversion systems (WECS) - Wind turbine operating systems - Solar photovoltaic (PV) systems - Types of PV cell - Small-scale hydroelectric power generation - Other renewable energy sources - Storage devices - Island mode of operation Power quality.

UNIT II VOLTAGE AND CURRENT CONTROL IN DISTRIBUTED GENERATION SYSTEMS 9

Distributed energy system description - DGS control requirements - Distributed generation system modeling - Control system design- Load sharing control algorithm - Power converter system - control theory: perfect control of robust servomechanism problem - discrete-time sliding mode control - control system development - step-by-step control flow explanations.

UNIT III PROTECTION ISSUES FOR MICROGRID 9

Introduction - Islanding: separation from utility - Different islanding scenarios - Major protection issues of stand-alone Microgrid - Microgrid distribution system protection - Protection of microsources - Microgrids and active distribution networks - NEC requirements for distribution transformer protection - Neutral grounding requirements.

UNIT IV IMPACT OF DG INTEGRATION ON POWER QUALITY AND RELIABILITY 9

Power quality sensitive customers - Existing power quality improvement technologies - Alternative power supply technologies - Power-conditioning technologies - Impact of DG integration - Simple standby generation scheme - Secondary DG system with power quality support - Primary DG system with power quality support to priority loads - Soft grid-connected DG with power quality support to priority loads - DG with intermittent solar PV within power quality environment - DG with intermittent wind generator within power quality environment - Ultra-high reliability scheme using dual link DC bus - Issues of premium power in DG integration.

UNIT V POWER FLOW CONTROL OF A SINGLE DISTRIBUTED GENERATION UNIT 9

Introduction - Real and reactive power control problems - Conventional integral control - Stability problem – Newton–Raphson parameter estimation and feedforward control Newton– Raphson parameter identification - Harmonic power control.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Analyze various types of distributed energy resources.

CO2: Analyze the configurations and control aspects of distributed generation systems.

CO3: Describe the protection schemes of microgrid system.

CO4: Analyze the impact of grid integration on power quality and reliability.

CO5: Explain about power flow control of a single distributed generation unit.

REFERENCES:

1. S. Chowdhury, S.P. Chowdhury and P. Crossley, 2009. *Microgrids and Active Distribution Networks*, The Institution of Engineering and Technology.
2. Keyhani, A., Marwali, M.N. and Dai, M., 2009. *Integration of green and renewable energy in electric power systems*. John Wiley & Sons.
3. Shahnia, F., Majumder, R., Ghosh, A., Ledwich, G. and Zare, F., 2010. Operation and control of a hybrid microgrid containing unbalanced and nonlinear loads. *Electric Power Systems Research*, *80*(8), pp.954-965.
4. Wang, Y., Zhang, P., Li, W., Xiao, W. and Abdollahi, A., 2012. Online overvoltage prevention control of photovoltaic generators in microgrids. *IEEE Transactions on Smart Grid*, *3*(4), pp.2071-2078.
5. Etemadi, A.H. and Iravani, R., 2012. Overcurrent and overload protection of directly voltage-controlled distributed resources in a microgrid. *IEEE Transactions on Industrial Electronics*, *60*(12), pp.5629-5638.
6. Ahn, S.J., Park, J.W., Chung, I.Y., Moon, S.I., Kang, S.H. and Nam, S.R., 2010. Power-sharing method of multiple distributed generators considering control modes and configurations of a microgrid. *IEEE Transactions on Power Delivery*, *25*(3), pp.2007-2016.

PS1339	DESIGN OF SUBSTATIONS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To provide in-depth knowledge on design criteria of Air Insulated Substation (AIS) and Gas Insulated Substation (GIS).
- To obtain the knowledge about layout of AIS and GIS with proper Right of Way.
- To study the substation insulation co-ordination and protection scheme.
- To study the source and effect of fast transients in AIS and GIS.

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 standards.

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

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Outline the fundamental components of AIS and GIS.
CO2: Describe the role of major equipment and layout of AIS and GIS
CO3: Relate the insulation coordination of AIS and GIS.
CO4: Discuss the significance of grounding and shielding.
CO5: Summarize the effects of fast transients in Substation equipment.

REFERENCES:

1. Hileman, A.R., 2018. *Insulation coordination for power systems*. CRC Press.
2. Naidu, M.S., 2008. *Gas Insulated Substations: Gis*. IK International Pvt Ltd.
3. Ragaller, K., 1980. Surges in high-voltage networks. Plenum Publishing Corporation, New York.
4. *Power Engineer's Handbook*, TNEB Association.
5. Chowdhuri, P., 1996. *Electromagnetic transients in power systems*. Somersent: Research Studies Press.
6. *Stockton, B., 2016. Design Guide for Rural Substations. PDF). USDA Rural Development. United States Department of Agriculture. Retrieved, 4.*
7. *Report, A.C., 1953. Substation One-Line Diagrams [includes discussion]. Transactions of the American Institute of Electrical Engineers. Part III: Power Apparatus and Systems, 72(4), pp.747-752.*
8. Koch, H.J. ed., 2014. *Gas insulated substations*. John Wiley & Sons.

PS1340	ELECTRICAL SAFETY & HAZARD MANAGEMENT	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To summarize basics of industrial safety.
- To describe fundamentals of maintenance engineering.
- To explain wear and corrosion.
- To illustrate fault tracing.
- To conduct safety audit and write audit reports effectively.

UNIT I INTRODUCTION 9

Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods

UNIT II FUNDAMENTALS OF MAINTENANCE ENGINEERING 9

Definition and aim of maintenance engineering, Types of maintenance, Functions and responsibility of maintenance department, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment-Periodic inspection-overhauling of electrical motor, common troubles and remedies of electric motor- Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generation (DG) sets

UNIT III WEAR AND CORROSION AND THEIR PREVENTION 9

Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

UNIT IV FAULT TRACING 9

Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, i. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

UNIT V ACCIDENT INVESTIGATION AND SAFETY AUDIT 9

Concept of an accident and types, principles of accident prevention – accident investigation and analysis – records for accidents, documentation of accidents – unsafe act and condition – domino sequence – role of safety committee –cost of accident-Components of safety audit, audit methodology, non-conformity reporting (NCR), audit checklist and report – review of inspection – check list – identification of unsafe acts of workers and unsafe conditions in the shop floor-IS 14489 : 1998 Code of practice on occupational Safety and health audit

TOTAL:45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

- CO1: Describe the basics and need for industrial safety.
- CO2: Discuss the various functions and tools used in maintenance engineering.
- CO3: Elaborate impacts of wear and corrosion & their prevention measures.
- CO4: Infer the occurrence of faults in various machine tools.
- CO5: Examine the causes for accident and prepare audit report effectively.

REFERENCES:

1. Garg H P, 1987.*Maintenance Engineering*, S. Chand and Company.
2. Hans F. Winterkorn, 2013.*Foundation Engineering Handbook*, Chapman & Hall London.
3. Higgins & Morrow, 2008. *Maintenance Engineering Handbook*, Eighth Edition.

PS1341	ENERGY EFFICIENT BUILDING MANAGEMENT SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To understand the need for energy efficient buildings
- To acquire knowledge on the utilization of solar energy to be accounted during building design
- To understand about the concept of passive solar heating.
- To impart knowledge about the various energy conservation techniques in buildings
- To provide knowledge about energy efficient technologies

UNIT I ENVIRONMENTAL IMPLICATIONS OF BUILDINGS 9

Energy use, carbon emissions, water use, waste disposal - Building materials: sources, methods of production and environmental Implications - Embodied Energy in Building Materials - Transportation Energy for Building Materials - Maintenance Energy for Buildings.

UNIT II PRINCIPLES OF ENERGY CONSCIOUS BUILDING DESIGN 9

Energy conservation in buildings – Day lighting – Water heating and photovoltaic systems – Advances in thermal insulation – Heat gain/loss through building components – Solar architecture - Green Buildings – Indian Green Building council ratings for New and Existing buildings.

UNIT III ENERGY CONSERVATION IN BUILDING 9

Air conditioning – HVAC equipments – Computer packages for thermal design of buildings and performance prediction – Monitoring and instrumentation of passive buildings – Building Automation systems – Illustrative passive buildings – Integration of emerging technologies – Intelligent building design principles.

UNIT IV LIGHTING SYSTEMS & COGENERATION 9

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

UNIT V EFFICIENT TECHNOLOGIES IN ELECTRICAL SYSTEMS 9

Maximum demand controllers - Automatic power factor controllers - Energy efficient motors and soft starters - Energy efficient Transformers, Energy Efficient Lighting systems -Occupancy sensors- Energy Performance index

TOTAL:45 PERIODS

OUTCOMES:

Upon completion of this course, Students will be able to

CO1: Describe the energy spent in rising a building and carbon emission.
CO2: Outline the ways in which solar energy can be utilized in building.
CO3: Apply energy conservation techniques in buildings
CO4: Demonstrate the various lighting systems and optimization of lighting systems
CO5: Apply energy efficient technologies in the electrical systems of buildings.

REFERENCES:

1. Clarke, J.A. and Clarke, J.A., 2001. *Energy simulation in building design*. Routledge.
2. Nayak, J.K. and Prajapati, J.A., 2006. Handbook on energy conscious buildings. *Prepared under the interactive R & D project*, *3*(4), p.03.
3. Balcomb, J.D., 1983. *Passive Solar Design Handbook: Passive solar design analysis and supplement* (Vol. 3). American Solar Energy Society.
4. Threlkeld, J.L., 1970. *Thermal environmental engineering* (Vol. 11). Prentice Hall.
5. Thumann, A. and Mehta, D.P., 2001. *Handbook of energy engineering*. CRC Press.

PS1342	IOT FOR POWER ENGINEERS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To understand the fundamentals of Internet of Things
- To learn about the basics of IOT protocols
- To build a small low cost embedded system using Raspberry Pi.
- To apply the concept of Internet of Things in the Power system Application.

UNIT I INTRODUCTION TO IoT 9

Internet of Things - Physical Design- Logical Design- IoT Enabling Technologies - IoT Levels & Deployment Templates - Domain Specific IoTs - IoT and M2M - IoT System Management with NETCONF-YANG- IoT Platforms Design Methodology

UNIT II IoT ARCHITECTURE 9

M2M high-level ETSI architecture - IETF architecture for IoT - OGC architecture - IoT reference model - Domain model - information model - functional model - communication model - IoT reference architecture

UNIT III IoT PROTOCOLS 9

Protocol Standardization for IoT – Efforts – M2M and WSN Protocols – SCADA and RFID Protocols – Unified Data Standards – Protocols – IEEE 802.15.4 – BACNet Protocol – Modbus– Zigbee Architecture – Network layer – 6LowPAN - CoAP – Security

UNIT IV BUILDING IoT WITH RASPBERRY PI & ARDUINO 9

Building IOT with RASPERRY PI- IoT Systems - Logical Design using Python – IoT Physical Devices & Endpoints - IoT Device -Building blocks -Raspberry Pi -Board - Linux on Raspberry Pi - Raspberry Pi Interfaces -Programming Raspberry Pi with Python - Other IoT Platforms - Arduino.

UNIT V POWER SYSTEM APPLICATIONS 9

Real world design constraints - Applications - Asset management, Industrial automation, smart grid, Home automation, Commercial building automation, Smart cities - participatory sensing - Data Analytics for IoT, Electric vehicle and intelligent transportation systems.

TOTAL: 45 PERIODS

OUTCOMES:

Upon Successful Completion of this course, the students will be able to

CO1: Interpolate the fundamentals of Internet of Things.

CO2: Discuss the various architectures and models for IoT.

CO3: Analyze various protocols for IoT.

CO4: Design a portable IoT using Rasperry Pi & Arduino.

CO5: Examine applications of IoT in power systems applications.

REFERENCES:

1. Bahga, A. and Madisetti, V., 2014. *Internet of Things: A hands-on approach*. Vpt.
2. Uckelmann, D., Harrison, M. and Michahelles, F., 2011. An architectural approach towards the future internet of things. In *Architecting the internet of things* (pp. 1-24). Springer, Berlin, Heidelberg.
3. Zhou, H., 2012. *The internet of things in the cloud: A middleware perspective*. CRC press.
4. Holler, J., Tsiatsis, V., Mulligan, C., Avesand, S., Karnouskos, S. and Boyle, D., 2015. From machine-to-machine to the internet of things.
5. Hersent, O., Boswarthick, D. and Elloumi, O., 2011. *The internet of things: Key applications and protocols*. John Wiley & Sons.