M.KUMARASAMY COLLEGE OF ENGINEERING

(An Autonomous Institution and Affiliated to Anna University Chennai)

KARUR – 639 113

PG

CURRICULUM AND SYLLABUS
M.E. POWER SYSTEMS ENGINEERING

REGULATION 2019

CURRICULUM AND SYLLABUS

REGULATION 2019

Programme: M.E. – POWER SYSTEMS ENGINEERING

Vision of the Department:

To produce smart and dynamic professionals with profound theoretical and practical knowledge comparable with the best in the field.

Mission of the Department:

M1: Produce hi-tech professionals in the field of Electrical and Electronics Engineering by inculcating core knowledge.

M2: Produce highly competent professionals with thrust on research.

M3: Provide personalized training to the students for enriching their skills.

Programme Educational Objectives (PEO's)

PEO1: Graduates of theprogramme will have excellent career in power sectors and its related disciplines.

PEO2: Graduates of the programme will have technical competency in solving challenging societal tasks in ethical and economical manner.

PEO3: Graduates of the programme will reveal lifelong learning and team work in their chosen profession.

Programme Outcomes (POs)

PO1: Students have an ability to independently carry out research /investigation and development work to solve practical problems

PO2: Students have an ability to write and present a substantial technical report/document

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO4:Students have an ability to analyse problems related to Power Systems and be able to synthesise the domain knowledge and incorporate the principles in the state of art systems for further enrichment

PO5:Students should be able to critically investigate the prevailing complex Power System scenarios and arrive at possible solutions independently, by applying the acquired theoretical and practical knowledge

PO6:Students should be able to identify optimal solutions for improvising power transfer capability, enhancing power quality and reliability.

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Structure of Curriculum

Sl.No.	Category	Credits
1	Basic Science courses (B)	04
2	Professional core courses (C)	23
3	Professional Elective courses relevant to chosen specialization/branch (E)	18
4	Project work, Minor project, seminar and internship in industry or elsewhere (P)	22
5	Mandatory Courses (M)	02
	Total Credits	69*

*Minor variation is allowed as per need of the respective disciplines.

1. Basic Science courses (B)

Course Code	Course Name	Hours / Week			C
		L	T	P	
19PPSB101T	Applied Mathematics for Electrical Engineers	3	1	0	4
				Total Credits	04

L-Lecture T-Tutorial P-Practical

2. Professional core courses (C)

Course Code	**Course Name**	**Hours / Week**			**C**
		L	**T**	**P**	
19PPSC101T	Advanced Power System Analysis	3	1	0	4
19PPSC102T	Advanced Power System Operation and Control	3	0	0	3
19PPSC103T	System Theory	3	0	0	3
19PPSC104L	Power System Simulation Laboratory	0	0	3	2
19PPSC105T	Power System Dynamics	3	0	0	3
19PPSC106T	Power Electronics Application to Power Systems	3	0	0	3
19PPSC107T	Restructured Power Systems	3	0	0	3
19PPSC108L	Power Electronics Application to Power Systems Laboratory	0	0	3	2
				Total Credits	**23**

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3. Professional Elective courses relevant to chosen specialization/branch (E) (Any 6 Subjects)

Course Code	Course Name	Hours / Week			C
		L	T	P	
SEMESTER I – Elective I					
19PPSE001T	Modeling and Analysis of Electrical Machines	3	0	0	3
19PPSE002T	Power Converters for Renewable Energy Sources	3	0	0	3
19PPSE003T	Power System Planning and Reliability	3	0	0	3
SEMESTER II - Elective II & III					
19PPSE004T	Power System Economics	3	0	0	3
19PPSE005T	Control System Design	3	0	0	3
19PPSE006T	EHVAC Transmission	3	0	0	3
19PPSE007T	Electrical Transients in Power Systems	3	0	0	3
19PPSE008T	Energy Management and Auditing	3	0	0	3
19PPSE009T	Power Distribution Systems	3	0	0	3
SEMESTER III - Elective IV, V & VI					
19PPSE010T	Advanced Power System Dynamics	3	0	0	3
19PPSE011T	Smart Grid	3	0	0	3
19PPSE012T	High Voltage Direct Current Transmission	3	0	0	3
19PPSE013T	Industrial Power System Analysis and Design	3	0	0	3
19PPSE014T	Optimal Control and Filtering	3	0	0	3
19PPSE015T	Solar and Energy Storage Systems	3	0	0	3
19PPSE016T	Optimization Techniques	3	0	0	3
19PPSE017T	Power System Stability	3	0	0	3
19PPSE018T	Wind Energy Conversion Systems	3	0	0	3
19PPSE019T	Power System Protection	3	0	0	3
				Total Credits	18*

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4. Project work, minor project, seminar and internship in industry or elsewhere (P)

Course Code	Course Name	Hours / Week			C
		L	T	P	
19PPSP101L	Mini Project	0	0	4	2
19PPSP102L	Project Work (Phase –I)	0	0	12	6
19PPSP103L	Project work (Phase –II)	0	0	28	14
				Total Credits	22

L-Lecture T-Tutorial P-Practical

5. Mandatory Courses (M)

Course Code	Course Name	Hours / Week			C
		L	T	P	
19PATM101	Research Methodology and IPR	2	0	0	2
19PATM102	English for Research Paper Writing	1	0	0	0
19PATM103	Pedagogy Studies	1	0	0	0
				Total Credits	2

L-Lecture T-Tutorial P-Practical

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I to IV Semester Curriculum

Semester I						
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
B	19PPSB101T	Applied Mathematics for Electrical Engineers	3	1	0	4
C	19PPSC101T	Advanced Power System Analysis	3	1	0	4
C	19PPSC102T	Advanced Power System Operation and Control	3	0	0	3
C	19PPSC103T	System Theory	3	0	0	3
E	19PPSEXXXT	Elective I	3	0	0	3
C	19PPSC104L	Power System Simulation Laboratory	0	0	3	2
M	19PATM101	Research Methodology and IPR	2	0	0	2
M	19PATM102	English for Research Paper Writing	1	0	0	0
					Total Credits	21

Semester II						
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC105T	Power System Dynamics	3	0	0	3
C	19PPSC106T	Power Electronics Application to Power Systems	3	0	0	3
C	19PPSC107T	Restructured Power Systems	3	0	0	3
E	19PPSEXXXT	Elective II	3	0	0	3
E	19PPSEXXXT	Elective III	3	0	0	3
C	19PPSC108L	Power Electronics Application to Power Systems Laboratory	0	0	3	2
P	19PPSP101L	Mini Project	0	0	4	2
M	19PATM103	Pedagogy Studies	1	0	0	0
					Total Credits	19

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Semester III						
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSEXXXT	Elective IV	3	0	0	3
E	19PPSEXXXT	Elective V	3	0	0	3
E	19PPSEXXXT	Elective VI	3	0	0	3
P	19PPSP102L	Project Work (Phase –I)	0	0	12	6
					Total Credits	15

Semester IV						
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
P	19PPSP103L	Project work (Phase –II)	0	0	28	14
					Total Credits	14

L-Lecture T-Tutorial P-Practical

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TOTAL CREDITS = 69

Regulation 2019		Semester I	Total Hours			60
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
B	19PPSB101T	APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS	3	1	0	4

Course Objective (s):

The purpose of learning this course is to:

1	Develop the ability to apply the concepts of matrix theory in electrical engineering problems.
2	Develop the ability to apply the concepts of linear programming in electrical engineering problems.
3	Achieve an understanding of the basic concepts of one dimensional random variables and apply it in electrical engineering problems.
4	Study the single server and multiple server models used in electrical engineering problems.
5	Develop the ability to apply the Numerical techniques to solve the problems in electrical engineering problems.

Course Outcome (s) (Cos):

At the end of this course, learners will be able to:

CO1	Apply various methods in matrix theory to solve system of linear equations.
CO2	Develop a fundamental understanding of linear programming models and apply the simplex method for solving linear programming problems.
CO3	Understand computation of probability and moments, standard distributions of discrete and continuous random variables and functions of a random variable.
CO4	Apply the basic concepts of single server and multiple server models in queue design.
CO5	Use Numerical techniques tosolve electrical engineering problems.

UNIT I	ADVANCED MATRIX THEORY	12

Eigen values using QR transformations – Generalized Eigen vectors – Canonical forms – Singular value decomposition and applications – Pseudo inverse – Least square approximations.

UNIT II	LINEAR PROGRAMMING	12

Formulation – Graphical Solution – Simplex Method – Two Phase Method – Transportation and Assignment problems.

UNIT III	ONE DIMENSIONAL RANDOM VARIABLES	12

Random variables - Probability function – Moments – Moment generating functions and their properties –Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Functions of a random variable.

UNIT IV	QUEUEING MODELS	12

Poisson Process – Markovian queues – Single and Multi-Server Models – Little's formula – Machine Interference Model – Steady state analysis – Self service queue.

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UNIT V	NON-LINEAR PROGRAMMING	12
Lagrange multipliers - Equality constraints - Inequality constraints - Kuhn - Tucker conditions - Quadratic programming.		
Text Book (s)		
1	Winston.W.L. "Operations Research", Fourth Edition, Thomson - Brooks/Cole, 2003.	
2	Taha, H.A. "Operations Research: An Introduction", Ninth Edition, Pearson Education Edition, Asia, New Delhi, 2002.	
Reference (s)		
1	Robertazzi. T.G. "Computer Networks and Systems - Queuing Theory and Performance Evaluation", Third Edition, Springer, 2002 Reprint.	
2	Ross. S.M., "Probability Models for Computer Science", Academic Press, 2002.	

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Regulation 2019		Semester I	Total Hours			60
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC101T	ADVANCED POWER SYSTEM ANALYSIS	3	1	0	4

Prerequisite Course (s)

NIL

Course Objective (s):

The purpose of learning this course is to

1	Introduce different techniques of dealing with sparse matrix for large scale power systems.
2	Impart in-depth knowledge on different methods of power flow solutions.
3	Perform optimal power flow solutions in detail.
4	Perform short circuit fault analysis and understand the consequence of different type of faults.
5	Illustrate different numeric al integration methods and factors influencing transient stability

Course Outcome (s) (COs):

At the end of the course students will be able to

CO1	Discuss different techniques dealing with sparse matrix for large scale power systems
CO2	Explain different methods of power flow solutions
CO3	Solve optimal power flow problem.
CO4	Analyze various types of short circuit faults
CO5	Demonstrate different numeric al integration methods and factors influencing transient stability

UNIT I	SOLUTION TECHNIQUE	12
Sparse Matrix techniques for large scale power systems: Optimal ordering schemes for preserving sparsity. Flexible packed storage scheme for storing matrix as compact arrays – Factorization by Bifactorization and Gauss elimination methods; Repeat solution using Left and Right factors and L and U matrices.		

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UNIT II	POWER FLOW ANALYSIS	12

Power flow equation in real and polar forms; Review of Newton's method for solution; Adjustment of P-V buses; Review of Fast Decoupled Power Flow method; Sensitivity factors for P-V bus adjustment; Net Interchange power control in Multi-area power flow analysis: ATC, Assessment of Available Transfer Capability (ATC) using Repeated Power Flow method; Continuation Power Flow method.

UNIT III	OPTIMAL POWER FLOW	12

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

UNIT IV	SHORT CIRCUIT ANALYSIS	12

Fault calculations using sequence networks for different types of faults. Bus impedance matrix (Z_{BUS}) construction using Building Algorithm for lines with mutual coupling; Simple numerical problems. Computer method for fault analysis using Z_{BUS} and sequence components. Derivation of equations for bus voltages, fault current and line currents, both in sequence and phase domain using Thevenin's equivalent and Z_{BUS} matrix for different faults.

UNIT V	TRANSIENT STABILITY ANALYSIS	12

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

Reference (s)

1	G W Stagg , A.H El. Abiad "Computer Methods in Power System Analysis", McGraw Hill, 1968.
2	P.Kundur, "Power System Stability and Control", McGraw Hill, 2006.
3	A.J.Wood and B.F.Wollenberg, "Power Generation Operation and Control", John Wiley and sons, New York, 2013.
4	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.
5	K.Zollenkopf, "Bi-Factorization : Basic Computational Algorithm and Programming Techniques ; pp:75-96 ; Book on "Large Sparse Set of Linear Systems" Editor: J.K.Rerd,Academic Press, 2004.

Regulation 2019		Semester I	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC102T	ADVANCED POWER SYSTEM OPERATION AND CONTROL	3	0	0	3

Prerequisite Course (s)
NIL

Course Objective (s):
The purpose of learning this course is to

1	Illustrate the importance of reactive power and voltage control in a power system.
2	Elaborate the various methods of solving the unit commitment problems.
3	Summarize the various methods of solving the economic dispatch problems.
4	Describe the process which is involved in interchange of power and energy.
5	Discuss the role of AGC, SCADA and EMS in the control of power system.

Course Outcome (s) (COs):
At the end of this course, learners will be able to:

CO1	Analyze the suitable compensating devices to control the reactive power and voltagein a power system.
CO2	Determine the solutions for the unit commitment problems by using advanced methods.
CO3	Solve the economic dispatch problems in an effective way.
CO4	Describe the parties involved in the transaction process of power and energy.
CO5	Elaborate the various automation tools involved in the control of power system.

UNIT I	REACTIVE POWER AND VOLTAGE CONTROL	9

Production and absorption of reactive power- Methods of Voltage Control – Shunt reactors – Shunt Capacitors – Series Capacitors – Synchronous condensers – Static Var systems – Principles of Transmission system compensation – Modeling of reactive compensating devices – Application of tap changing transformers to transmission systems – Distribution system voltage regulation – Modelling of transformer ULTC control systems.

UNIT II	UNIT COMMITMENT	9

Constraints in unit commitment – Spinning reserve – Thermal unit constraints – Other constraints – Solution using Priority List method, Dynamic programming method - Forward DP approach Lagrangian relaxation method – adjusting λ.

UNIT III	GENERATION SCHEDULING	9

The Economic dispatch problem – Thermal system dispatching with network losses considered – The Lambda – iteration method – Gradient method of economic dispatch – Economic dispatch with Piecewise Linear cost functions – Transmission system effects – A two generator system – coordination equations – Incremental losses and penalty factors-Hydro Thermal Scheduling using DP.

UNIT IV	INTERCHANGE OF POWER AND ENERGY	9

Economy interchange between interconnected utilities - interchange evaluation with unit commitment - multiple - utility interchange transactions - power pools - the energy broker system - allocating pool savings - transmission effects and issues - transfer limitations - wheeling - rates for transmission services in multiparty utility transactions - transactions involving non-utility parties.

UNIT V	CONTROL OF POWER SYSTEMS	9

Introduction to state estimation- Review of AGC and reactive power control -System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis – Corrective controls (Preventive, emergency and restorative) - Energy control center – SCADA system – Functions – monitoring , Data acquisition and controls – EMS system.

Reference (s)

1	O.I.Elgerd, "Electric Energy System Theory - an Introduction", - Tata McGraw Hill, New Delhi – 2004.
2	P.Kundur ; "Power System Stability and Control", EPRI Publications, California , 2006.
3	Allen J.Wood and Bruce.F.Wollenberg, "Power Generation Operation and Control', John Wiley &Sons , New York, 2013.
4	A.K.Mahalanabis, D.P.Kothari. andS.I.Ahson., "Computer Aided Power System Analysis and Control", Tata McGraw Hill publishing Ltd , 1989.

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Regulation 2019		Semester I	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC103T	SYSTEM THEORY	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):

The purpose of learning this course is to

1	Understand the fundamentals of physical systems in terms of its linear and nonlinear models.
2	Educate on solving linear and non-linear state equations
3	Exploit the properties of linear systems such as controllability and observability
4	Impart knowledge on stability analysis of systems using Lyapunov's theory
5	Educate on modal concepts and design of state and output feedback controllers and estimators

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Describe the state variable types and its representation
CO2	Derive the output of the homogeneous and non-homogeneous system using Eigen values and vectors
CO3	Determine the system characteristics using controllability and observability
CO4	Analyse the stability of non-linear system using different techniques.
CO5	Modelling the system using state variable techniques.

UNIT I	STATE VARIABLE REPRESENTATION	9

Introduction-Concept of State-State equation for Dynamic Systems-Time invariance and linearity-Nonuniqueness of state model-State Diagrams-Physical System and State Assignment.

UNIT II	SOLUTION OF STATE EQUATION	9

Existence and uniqueness of solutions to Continuous-time state equations-Solution of Nonlinear and Linear Time Varying State equations-Evaluation of matrix exponential-System modes-Role of Eigenvalues and Eigenvectors.

UNIT III	CONTROLLABILITY AND OBSERVABILITY	9
Controllability and Observability-Stabilizability and Detectability-Test for Continuous time Systems- Time varying and Time invariant case-Output Controllability-Reducibility-System Realizations.		
UNIT IV	**STABILITY**	**9**
Introduction-Equilibrium Points-Stability in the sense of Lyapunov-BIBO Stability-Stability of LTI Systems-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 and Variable-Gradiant Method.		
UNIT V	**MODAL CONTROL**	**9**
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.		

Reference (s)

1	M. Gopal, "Modern Control System Theory", New Age International, 2014.
2	K. Ogatta, "Modern Control Engineering", PHI, 2011.
3	John S. Bay, "Fundamentals of Linear State Space Systems", McGraw-Hill, 1999
4	D. Roy Choudhury, "Modern Control Systems", New Age International, 2005.
5	John J. D'Azzo, C. H. Houpis and S. N. Sheldon, "Linear Control System Analysis and Design with MATLAB", Taylor Francis, 2003.
6	Z. Bubnicki, "Modern Control Theory", Springer, 2005.

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Regulation 2019		Semester I	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC104L	POWER SYSTEM SIMULATION LABORATORY	0	0	3	2

Prerequisite Course (s)

NIL

Course Objective (s):

The purpose of learning this course is to

1	Present a problem oriented knowledge of power system analysis methods.
2	Address the underlying concepts and approaches behind analysis of power system network using software tools.
3	Identify and analysis of electrical system through computer simulation using software packages.

Course Outcome (s) (Cos):

At the end of this course, learners will be able to

CO1	Analyze power flow problem of Newton-Raphson and Fast decoupled method using software and to develop coding to solve power flow problems.
CO2	Analyze the transient stability of SMIB system and to calculate Generator shift factors, line outage distribution factors using software.
CO3	Design and solve the Economic dispatch, Unit commitment problems in Power system.
CO4	Analyze the switching surges in power system network using given software.
CO5	Analyze the stability of power system network using given software.

List of Experiment(s)	
1	Power flow analysis by Newton-Raphson method
2	Power flow analysis by Fast decoupled method
3	Transient stability analysis of single machine-infinite bus system using classical machine model
4	Contingency analysis: Generator shift factors and line outage distribution factors
5	Economic dispatch using lambda-iteration method
6	Unit commitment: Priority-list schemes and dynamic programming
7	Analysis of switching surge using software: Energisation of a long distributed-parameter line
8	Analysis of switching surge using software: Computation of transient recovery voltage
9	State estimation in power system.
10	Analysis of rotor angle stability using swing equation

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Regulation 2019		Semester I	Total Hours			30
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
M	19PATM101	Research Methodology and IPR	2	0	0	2

Prerequisite Course (s)

Nil

Course Objective (s):

The purpose of learning this course is to:

1	Understand and analyse the fundamental of research problem
2	Understand the Research Ethics
3	Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity
4	Understand Intellectual Property Rights
5	Understand Patents Rights

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Understand research problem formulation
CO2	Analyze research related information
CO3	Follow research ethics
CO4	Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular
CO5	Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits

UNIT I	INTRODUCTION	6

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	ANALYSIS OF REARCH	6

Approaches of investigation of solutions for research problem- data collection- analysis- interpretation- Necessary instrumentations Effective literature studies approaches- analysis Plagiarism,- Research ethics.

UNIT III	RESEACRH PRPOSAL AND TECHNICAL WRITING	6

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	INTELLECTUAL PROPERTY	6

Nature of Intellectual Property: Patents –Designs - Trade and Copyright- Process of Patenting and

Development: technological research- innovation- patenting- And development. International Scenario: International cooperation on Intellectual Property- Procedure for grants of patents- Patenting under PCT.		
UNIT V	**PATENTS RIGHTS**	**6**
Patent Rights: Scope of Patent Rights- Licensing and transfer of technology -Patent information and databases- Geographical Indications.		

Text Book (s)	
1	Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students".
2	Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007

Reference (s)	
1	Ranjit Kumar, 2 nd Edition , "Research Methodology: A Step by Step Guide for beginners"
2	T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
3	Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
4	Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"

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Regulation 2019		Semester I	Total Hours			15
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
M	19PATM102	English For Research Paper Writing	1	0	0	0

Prerequisite Course (s)
Nil

Course Objective (s):

The purpose of learning this course is to:

1	Understand that how to improve your writing skills and level of readability
2	Learn about what to write in each section
3	Understand the skills needed when writing a Title

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Understand the basics of writing skills
CO2	Illustrate the level of readability
CO3	Explain about what to write in each section
CO4	Summarize the skills needed to form a title

UNIT I	3
Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness	
UNIT II	**3**
Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction	
UNIT III	**3**
Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.	
UNIT IV	**3**
Key skills are needed when writing a title, Key skills are needed when writing an abstract, Key skills are needed when writing an introduction, Skills needed when writing a review of the literature	
UNIT V	**3**
Skills are needed when writing the methods, Skills needed when writing the results, Skills are needed when writing the discussion, Skills are needed when writing the conclusions, Useful Phrases, How to ensure paper is as good as it could possibly be the first- Time Submission	

Reference (s)	
1	Goldbort R (2006) Writing for Science, Yale University Press (available on Google Books)
2	Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press
3	Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM. Highman'sbook.
4	Adrian Wallwork, English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011

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Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC105T	POWER SYSTEM DYNAMICS	3	0	0	3

Prerequisite Course (s)

Advanced Power system operation and control

Course Objective (s):

The purpose of learning this course is to:

1	Model the synchronous machine with its mathematical descriptions.
2	Model the excitation and speed governing systems with its mathematical expressions.
3	Understand the effects of small signal stability without using the controllers.
4	Learn the effects of small signal stability while using the controllers.
5	Discuss the various methods to enhance the small signal stability.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Analyze the modelling of synchronous machine
CO2	Discuss the modelling of the excitation and speed governing systems.
CO3	Elaborate the effects of small signal stability without using the controllers.
CO4	Describe the effects of small signal stability while using the controllers.
CO5	Illustrate the various methods to enhance the small signal stability.

UNIT I	SYNCHRONOUS MACHINE MODELLING	9

Schematic Diagram, Physical Description: armature and field structure, machines with multiple pole pairs, mmf waveforms, direct and quadrature axes, Mathematical Description of a Synchronous Machine: Basic equations of a synchronous machine: stator circuit equations, stator self, stator mutual and stator to rotor mutual inductances, dq0 Transformation: flux linkage and voltage equations for stator and rotor in dq0 coordinates, electrical power and torque, physical interpretation of dq0 transformation, Per Unit Representations: L_{ad}-reciprocal per unit system and that from power-invariant form of Park's transformation; Equivalent Circuits for direct and quadrature axes, Steady-state Analysis: Voltage, current and flux-linkage relationships, Phasor representation, Rotor angle stability using swing equation.

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UNIT II	MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS	9
Excitation System Requirements; Elements of an Excitation System; Types of Excitation System;Control and protective functions;IEEE (1992) block diagram for simulation of excitation systems. Turbine and Governing System Modelling: Functional Block Diagram of Power Generation and Control, Schematic of a hydroelectric plant, classical transfer function of a hydraulic turbine (no derivation), special characteristic of hydraulic turbine, electrical analogue of hydraulic turbine, Governor for Hydraulic Turbine: Requirement for a transient droop, Block diagram of governor with transient droop compensation, Steam turbine modelling: Single reheat tandem compounded type only and IEEE block diagram for dynamic simulation; generic speed-governing system model for normal speed/load control function.		
UNIT III	SMALL-SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS	9
Classification of Stability, Basic Concepts and Definitions: Rotor angle stability, The Stability Phenomena. Fundamental Concepts of Stability of Dynamic Systems: State-space representation, stability of dynamic system, Linearisation, Eigen properties of the state matrix: Eigen values and eigenvectors, modal matrices, Eigen value and stability, mode shape and participation factor. Single-Machine Infinite Bus (SMIB) Configuration: Classical Machine Model stability analysis with numerical example, Effects of Field Circuit Dynamics: synchronous machine, network and linearised system equations, block diagram representation with K-constants; expression for K-constants (no derivation), effect of field flux variation on system stability: analysis with numerical example.		
UNIT IV	SMALL-SIGNAL STABILITY ANALYSIS WITH CONTROLLERS	9
Effects Of Excitation System: Equations with definitions of appropriate K-constants and simple thyristor excitation system and AVR, block diagram with the excitation system, Power System Stabiliser: Block diagram with AVR and PSS, Block diagram of PSS with description, Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix for a two-machine system with classical models for synchronous machines, Effect of multiband PSS(MBPSS).		
UNIT V	ENHANCEMENT OF SMALL SIGNAL STABILITY	9
Stabilizer based on shaft speed signal (delta omega) – Delta –P-Omega stabilizer-Frequency-based stabilizers – Digital Stabilizer – Excitation control design – Exciter gain – Phase lead compensation – Stabilizing signal washout stabilizer gain – Stabilizer limits		

Reference (s)

1	P. Kundur, "Power System Stability and Control", McGraw-Hill, 2006.
2	R.Ramanujam "Power System Dynamics: Analysis and Simulation". PHI Learning Pvt. Ltd., 2010
3	P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press, Ames, Iowa 2008.
4	Edward Wilson Kimbark "POWER SYSTEM STABILITY" IEEE press 2014
5	IEEE Committee Report, "Dynamic Models for Steam and Hydro Turbines in Power System Studies", IEEE Trans., Vol.PAS-92, pp 1904-1915, November/December, 1973. on Turbine-Governor Model.

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC106T	POWER ELECTRONICS APPLICATION TO POWER SYSTEMS	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):

The purpose of learning this course is to:

1	Acquire the knowledge on flexible AC Transmission System and its importance for FACTS controllers
2	Understand the various FACTS controllers operation on FACTS systems.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Apply knowledge of FACTS Controllers
CO2	Design a Compensators within realistic constraints.
CO3	Identify, formulate, and solve real network problems with FACTS controllers
CO4	Design a regulators and different configurations
CO5	Expand knowledge of recent trend in FACTS controllers and combined of FACTS controllers.

UNIT I	INTRODUCTION TO FACTS	9
Fundamentals of ac power transmission - Transmission problems and needs - Emergence of FACTS - FACTS control considerations - FACTS controllers.		

UNIT II	**SHUNT COMPENSATORS**	**9**
Principles of shunt compensation – Variable Impedance type & switching converter type - Static Synchronous Compensator (STATCOM) configuration - Characteristics and control.		
UNIT III	**SERIES COMPENSATORS**	**9**
Principles of static series compensation using GCSC, TCSC and TSSC – Applications - Static Synchronous Series Compensator (SSSC).		
UNIT IV	**REGULATORS**	**9**
Principles of operation - Steady state model and characteristics of a static voltage regulators and phase shifters - Power circuit configurations.		
UNIT V	**COMBINED COMPENSATORS**	**9**
UPFC - Principles of operation and characteristics - Independent active and reactive power flow control - Comparison of UPFC with the controlled series compensators and phase shifters. Interline Power Flow Controller (IPFC) – Basic Working and Control Structure.		

Reference (s)

1	Song, Y.H. and Allan T. Johns, 'Flexible AC Transmission Systems (FACTS)', Institution of Electrical Engineers Press, London, 1999.
2	Hingorani , L.Gyugyi, 'Concepts and Technology of Flexible AC Transmission System', IEEE Press New York, 2000 ISBN –078033 4588.
3	Mohan Mathur R. and Rajiv K.Varma, 'Thyristor - based FACTS controllers for Electrical transmission systems', IEEE press, Wiley Inter science , 2002.
4	Padiyar K.R., 'FACTS controllers for Transmission and Distribution systems', New Age International Publishers, 1st Edition, 2007.
5	Enrique Acha, Claudio R.Fuerte-Esqivel, Hugo Ambriz-Perez, Cesar Angeles-Camacho, 'FACTS – Modeling and simulation in Power Networks', John Wiley & Sons, 2002.

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC107T	RESTRUCTURED POWER SYSTEMS	3	0	0	3

Prerequisite Course (s)

Advanced Power System Operation And Control

Course Objective (s):
The purpose of learning this course is to:

1	Introduce the restructuring of power industry and market models.
2	Impart knowledge on fundamental concepts of congestion management.
3	Analyze the concepts of locational marginal pricing and financial transmission rights.
4	Understand various transmission pricing schemes
5	Illustrate about various power sectors in India

Course Outcome (s) (COs):
At the end of the course students will be able to:

CO1	Explain the importance of restructuring of Power Systems, different market models and the function of ISO role in power market.
CO2	Discuss the Concepts of Transmission Congestion and to calculate ATC
CO3	Calculate Locational marginal pricing and explain the significance of Financial Transmission rights.
CO4	Define Ancillary services management and analyze transmission pricing issues.
CO5	Outline the reform initiatives taken by Indian Government, Electricity act 2003 and open access issues.

UNIT I	FUNDAMENTALS OF POWER MARKETS	9

Fundamentals and structure of Restructured Power Market – Wheeling – Market Power - Power exchange and pool markets - Independent System Operator (ISO) – components - role of ISO - Operating Experiences of Restructured Electricity Markets in various Countries (UK, Australia, Europe, US, Asia).

UNIT II	TRANSMISSION CHALLENGES	9

Transmission expansion in the New Environment – Introduction – Role of transmission planning – Transmission Capacity – Total Transfer Capability (TTC) – Computational procedure – Margins – Available transfer capability (ATC) – Principles – Constraints - Methods to compute ATC

UNIT III	CONGESTION MANAGEMENT AND ANCILLARY SERVICES	9
Concept of Congestion Management – Methods to relieve the congestion - Inter and Intra zonal Congestion Management – Generation Rescheduling - Locational Marginal Pricing – Financial Transmission Right - Ancillary Services.		

UNIT IV	TRANSMISSION PRICING	9
Transmission pricing methods - Postage stamp - Contract path - MW-mile – MVA mile – Distribution Factor method – Tracing method - Short run marginal cost (SRMC) – Generator Ramping and Opportunity Costs.		

UNIT V	INDIAN POWER MARKET	9
Current Scenario – Regions – Salient features of Indian Electricity Act 2003 – Regulatory and Policy development in Indian power Sector – Availability based tariff – Necessity – Working Mechanism – Unscheduled Interchange Rate – Operation of Indian Power Exchange		

Reference (s)

1	M. Shahidehpour and M. Alomoush, "Restructuring Electrical Power Systems", Marcel Decker Inc., 2021.
2	M. Shahidehpour, H. Yamin and Z. Li, "Market Operations in Electric Power Systems", John Wiley & Sons, Inc., 2002.
3	Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder, "Operation of Restructured Power Systems", Kluwer Academic Publishers, 2012..
4	Loi Lei Lai, "Power system Restructuring and Regulation", John Wiley sons, 2002.
5	Scholarly Transaction Papers, Utility and Power Exchange web sites.

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
C	19PPSC108L	POWER ELECTRONICS APPLICATION TO POWER SYSTEMS LABORATORY	0	0	3	2

Prerequisite Course (s)

Power System Simulation Laboratory

Course Objective (s):

The purpose of learning this course is to:

1	To present a problem oriented knowledge of power system analysis methods.
2	To address the underlying concepts and approaches behind analysis of power system network using software tools.
3	To identify and analysis of electrical system through computer simulation using software packages.
4	To study the induction motor starting analysis.
5	To provide the knowledge of various issues affecting power quality by using suitable hardware and software packages.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Analyze the transient analysis of two-bus system with STATCOM, load flow analysis by SSSC.
CO2	Ability to design and solve the problems of Small-signal stability analysis.
CO3	Ability to develop and design the feasible protection systems needed for each main part of a power system network.
CO4	Ability to solve the congestion management problems.
CO5	Analyze the power quality issues, the harmonic sources and the effects of harmonic distortion.

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List of Experiment(s)	
1	Load flow and Transient analysis of two-bus system with STATCOM
2	Computation of harmonic indices generated by a rectifier feeding a R-L load
3	Load flow analysis by SSSC
4	Small-signal stability analysis of multi-machine configuration with classical machine model
5	Co-ordination of over-current and distance relays for radial line protection
6	Computation of HARMONICS generated by rectifier feeding load
7	Induction motor starting Analysis
8	D-Q analysis of synchronous machine
9	Congestion management
10	Calculation of voltage sag and swell using Power Quality Analyzer

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Regulation 2019		Semester II	Total Hours			15
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
M	19PATM103	Pedagogy Studies	1	0	0	0

Prerequisite Course (s)

Nil

Course Objective (s):

The purpose of learning this course is to:

1	Review existing evidence on the review topic to inform programme design and policy making undertaken by the DfID, other agencies and researchers.
2	Identify critical evidence gaps to guide the development.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
CO2	Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
CO3	Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
CO4	Discuss the passage of the Hindu Code Bill of 1956.

UNIT I	INTRODUCTION AND METHODOLOGY	3

Aims and rationale, Policy background, Conceptual framework and terminology, Theories of learning, Curriculum, Teacher education, Conceptual framework, Research questions, Overview of methodology and Searching

UNIT II	THEMATIC OVERVIEW	3

Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries, Curriculum, Teacher education

UNIT III	PEDAGOGIC STRATEGIES	3

Evidence on the effectiveness of pedagogical practices, Methodology for the in depth stage: quality assessment of included studies, How can teacher education (curriculum and practicum) and the school,curriculum and guidance materials best support effective pedagogy, Theory of change, Strength and nature of the body of evidence for effective pedagogical practices, Pedagogic theory and pedagogical approaches, Teachers' attitudes and Pedagogic strategies

UNIT IV	PROFESSIONAL DEVELOPMENT	3

Alignment with classroom practices and follow-up support ,Peer support, Support from the head teacher and the community, Curriculum and assessment, Barriers to learning: limited resources and large class sizes

UNIT V	RESEARCH GAPS AND FUTURE DIRECTIONS	3
Research design , Contexts, Pedagogy, Teacher education, Curriculum and assessment, Dissemination and research impact		

Text Book (s)

1	Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2): 245-261.
2	Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.

Reference (s)

1	Akyeampong K (2003) Teacher training in Ghana - does it count? Multi-site teacher education research project (MUSTER) country report 1. London: DFID.
2	Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33 (3): 272–282.
3	Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.

Regulation 2019		Semester I	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE001T	MODELING AND ANALYSIS OF ELECTRICAL MACHINES	3	0	0	3

Prerequisite Course (s)
Nil

Course Objective (s):
The purpose of learning this course is to:

1	Expose the students to learn the electromechanical energy conversion techniques
2	Learn the reference frame concepts in rotating electrical machines
3	Understand the static and dynamic characteristics of DC machines
4	Understand the static and dynamic characteristics of Induction machines
5	Understand the static and dynamic characteristics of Synchronous machines

Course Outcome (s) (COs):
At the end of the course students will be able to:

CO1	Apply the concepts related to electromechanical energy conversion techniques
CO2	Analyse the reference frame concepts in rotating electrical machines
CO3	Analyse the static and dynamic characteristics of DC machines
CO4	Analyse the static and dynamic characteristics of Induction machines
CO5	Analyse the static and dynamic characteristics of Synchronous machines

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UNIT I	PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION	9
General expression of stored magnetic energy, co-energy and force/ torque – example using single and doubly excited system –Calculation of air gap mmf and per phase machine inductance using physical machine data		
UNIT II	**REFERENCE FRAME THEORY**	**9**
Static and rotating reference frames – transformation of variables – reference frames – transformation between reference frames – transformation of a balanced set –balanced steady state phasor and voltage equations – variables observed from several frames of reference.		
UNIT III	**DC MACHINES**	**9**
Voltage and toque equations – dynamic characteristics of permanent magnet and shunt DC motors – state equations - solution of dynamic characteristic by Laplace transformation.		
UNIT IV	**INDUCTION MACHINES**	**9**
Voltage and toque equations – transformation for rotor circuits – voltage and toque equations in reference frame variables – analysis of steady state operation – free acceleration characteristics – dynamic performance for load and torque variations – dynamic performance for three phase fault – computer simulation in arbitrary reference frame.		
UNIT V	**SYNCHRONOUS MACHINES**	**9**
Voltage and Torque Equation – voltage Equation in arbitrary reference frame and rotor reference frame – Park equations - rotor angle and angle between rotor – steady state analysis – dynamic performances for torque variations- dynamic performance for three phase fault – transient stability limit – critical clearing time – computer simulation		

Reference (s)	
1	Samuel Seely, "Electromechanical Energy Conversion", Tata McGraw Hill Publishing Company, 1962.
2	A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, " Electric Machinery", Tata McGraw Hill, 5th Edition, 2013.
3	Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", IEEE Press, 2013
4	R.Krishnan, "Electric Motor Drives, Modeling, Analysis and Control" , Prentice Hall of India, 2002.

Regulation 2019		Semester I	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE002T	POWER CONVERTERS FOR RENEWABLE ENERGY SOURCES	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):
The purpose of learning this course is to:

1	Introduction to study of renewable energy resources and environmental electric energy conversion
2	Enumerate the power converters used in solar and wind energy conversion system
3	Understand about the voltage source inverters
4	Understand about the current source inverters and multilevel inverter
5	Acquire the basic knowledge of renewable energy sources

Course Outcome (s) (COs):
At the end of this course, learners will be able to:

CO1	Study of renewable energy resources and environmental electric energy conversion
CO2	Interpret power converters operation in solar and wind energy conversion system
CO3	Illustrate the concept of voltage source inverters and PWM techniques
CO4	Illustrate the current source inverters and multilevel inverter and its types
CO5	Explore about hybrid systems and case study of PV & wind energy conversion system

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UNIT I	INTRODUCTION	9
Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems.		
UNIT II	**POWER CONVERTERS**	**9**
Solar: Block diagram of solar photo voltaic system -Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection of inverter, battery sizing, array sizing Wind: Three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters.		
UNIT III	**VOLTAGE SOURCE INVERTERS**	**9**
Introduction of VSI & CSI - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – Three Phase Inverters with 180 degree and 120 degree conduction modes – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques.		
UNIT IV	**CURRENT SOURCE INVERTERS AND MULTILEVEL INVERTER**	**9**
Load commutated inverters – Auto sequential current source inverters (ASCI) – current pulsations (single & Three Phase) – comparison of current source inverter and voltage source inverters. Multilevel concept – diode clamped – flying capacitor – cascade type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters		
UNIT V	**RENEWABLE ENERGY SYSTEMS**	**9**
Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PV-Maximum Power Point Tracking (MPPT).		

Reference (s)

1	Rashid .M. H "power electronics Hand book", Academic press, 2010
2	Rai. G.D, "Non conventional energy sources", Khanna publishes, 2011
3	Rai. G.D," Solar energy utilization", Khanna publishes, 2004
4	Ned Mohan,Undeland and Robbin, "Power Electronics: converters, Application and design" John Wiley and sons.Inc,Newyork,2002.
5	P.S.Bimbhra, "Power Electronics", Khanna Publishers, 2012.

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Regulation 2019		Semester I	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE003T	POWER SYSTEM PLANNING AND RELIABILITY	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):

The purpose of learning this course is to:

1	Know the different methods of load forecasting
2	Understand basic concept of generation system relibility
3	Understand transmission system stability by fuzzy
4	Basic concept of expansion planning procedure
5	Know the various types of distribution system planning and protective devices

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Illustrate various methods of load forcasting
CO2	Analysis of generational load model and its reliability during demand
CO3	Analysis of transmission system stability by fuzzy
CO4	Enumerate various planning , procedure in transmission and distribution system
CO5	Understand overview of distribution system planning

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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	**GENERATION SYSTEM RELIABILITY ANALYSIS**	**9**
Probabilistic generation and load models- Determination of LOLP and expected value of demand not served –Determination of reliability of iso and interconnected generation systems.		
UNIT III	**TRANSMISSION SYSTEM RELIABILITY ANALYSIS**	**9**
Deterministic contingency analysis-probabilistic load flow-Fuzzy load flow probabilistic transmission system reliability analysis-Determination of reliability indices like LOLP and expected value of demand not served.		
UNIT IV	**EXPANSION PLANNING**	**9**
Basic concepts on expansion planning-procedure followed for integrate transmission system planning, current practice in India-Capacitor placer problem in transmission system and radial distributions system.		
UNIT V	**DISTRIBUTION SYSTEM PLANNING OVERVIEW**	**9**
Introduction, sub transmission lines and distribution substations-Design primary and secondary systems-distribution system protection and coordination of protective devices.		

Reference (s)

1	Proceeding of work shop on energy systems planning & manufacturing CI.
2	R.L .Sullivan, " Power System Planning",TMH-1977,.
3	Roy Billinton and Allan Ronald, "Power System Reliability.", Gordon and Breach,1970
4	Turan Gonen, Electric power distribution system Engineering 'McGraw Hill,2014

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE004T	POWER SYSTEM ECONOMICS	3	0	0	3

Prerequisite Course (s)
Advanced Power System Operation And Control

Course Objective (s):
The purpose of learning this course is to:

1	Explore the structure of electrical tariff and the impact of depreciation on the power components
2	Learn the fundamentals of minimizing the cost of generation sources
3	Meet the power system load are discussed with the aid of computational methods.

Course Outcome (s) (COs):
At the end of this course, learners will be able to:

CO1	Perform economic dispatch calculation.
CO2	Analyse optimal power flow for practical power system test data.

UNIT I	ECONOMIC CONSIDERATIONS	9
Cost of electrical energy - Expressions for cost of electrical energy – Capital-interest – Depreciation - Different methods - Factors affecting cost of operation - Number and size of generating units - Importance of high load factor - Importance of power factor improvement - Most economical power factor - Meeting the KW demand on power stations - Power system tariffs – Regions and structure of Indian Power System.		

UNIT II	ECONOMIC DISPATCH	9
Modeling of Cost Rate Curves – Economic Dispatch Calculation - Losses neglected, with generator Real and Reactive power limits; Losses included - Losses of economy in incremental cost data - Problems - Generator Capability Curve – Effect of Ramping rates – Prohibited Operating Zones - Automatic Load dispatch in Power Systems.		

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UNIT III	ECONOMIC OPERATION	9
General loss formula - Evolution of incremental transmission loss rate - Method of calculation of loss coefficients – Systematic development of transmission loss formula - Transmission loss as a function of plant generation – Participation Factor - Non – Smooth Fuel Functions (Quadratic, Valve point loading, CCCP, Multiple Fuel) – Problems - Introduction to Artificial Intelligence Techniques for solving ELD problems.		
UNIT IV	**ECONOMIC CONTROL**	**9**
Interconnected operation - Economic operation of hydro thermal power plants - Gradient approach – Newton's method - Modeling and solution approach to short term and long term Hydro-Thermal scheduling problem using Dynamic Programming.		
UNIT V	**OPTIMAL POWER FLOW AND FUNDAMENTALS OF MARKETS**	**9**
Problem formulation - Cost minimization - Loss minimization - Solution using NLP and successive LP methods – Constraints - DC and AC OPF (Real and Reactive Power Dispatch) – Fundamentals of Markets – Efficiency and Equilibrium - Modeling of consumers and producers bids – Global welfare – Dead Loss.		

Reference (s)	
1	Allen J Wood and B F Wollenberg, "Power Generation, Operation and Control", John Wiley & Sons, New York, 2013
2	HadiSaadat, "Power System Analysis", Second Edition, Tata McGraw Hill Publishers, 2010.
3	Steven Stoft, "Power System Economics", John Wiley & Sons, 2002.
4	Daniel S. Kirschen and GoranStrbac, "Power System Economics", John Wiley & Sons, Ltd, 2004.

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE005T	CONTROL SYSTEM DESIGN	3	0	0	3

Prerequisite Course (s)

System Theory

Course Objective (s):

The purpose of learning this course is to:

1	Acquire knowledge to design on controllers and compensator using time domain and frequency domain approach.
2	Learn the digital system design using IIR techniques.
3	Understand the formulation and evaluation of optimal control
4	Comprehend the state model using pole placement technique
5	Realize the state estimation using different techniques

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Design the controllers and the compensator using time domain and frequency domain approach.
CO2	Design of digital system using IIR techniques.
CO3	Formulate and evaluate the optimal control
CO4	Design of system model in discrete domain
CO5	Estimation of the system using different techniques like Luenberger's observer,Kalman-Bucy filter and separation theorem.

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UNIT I	**CONVENTIONAL DESIGN METHODS**	**9**
Design specifications- PID controllers and compensators- Root locus based design- Bode based design-Design examples.		
UNIT II	**DESIGN IN DISCRETE DOMAIN**	**9**
Sample and Hold-Digital equivalents-Impulse and step invariant transformations-Methods of discretisation-Effect of sampling- Direct discrete design – discrete root locusDesign examples.		
UNIT III	**OPTIMAL CONTROL**	**9**
Formation of optimal control problems-results of Calculus of variations- Hamiltonian formulation-solution of optimal control problems- Evaluation of Riccati's equationState and output Regulator problems-Design examples.		
UNIT IV	**DISCRETE STATE VARIABLE DESIGN**	**9**
Discrete pole placement- state and output feedback-estimated state feedback-discrete optimal control-dynamic programming-Design examples.		
UNIT V	**STATE ESTIMATION**	**9**
State Estimation Problem -State estimation- Luenberger's observer-noise characteristics- Kalman-Bucy filter-Separation Theorem-Controller Design-Wiener filter-Design examples.		

Reference (s)

1	M. Gopal "Modern control system Theory" New Age International, 2014.
2	Benjamin C. Kuo "Digital control systems", Oxford University Press, 2004.
3	G. F. Franklin, J. D. Powell and A. E. Naeini "Feedback Control of Dynamic Systems", PHI (Pearson), 2009.
4	Graham C. Goodwin, Stefan F. Graebe and Mario E. Salgado "Control system Design", PHI (Pearson), 2003.
5	G. F. Franklin, J. D. Powell and M Workman, "Digital Control of Dynamic Systems", PHI (Pearson), 2002.
6	B.D.O. Anderson and J.B. Moore., 'Optimal Filtering', Prentice hall Inc., N.J., 1979.
7	Loan D. Landau, GianlucaZito," Digital Control Systems, Design, Identification and Implementation", Springer, 2006.

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE006T	EHVAC TRANSMISSION	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):

The purpose of learning this course is to:

1	Impart knowledge on types of power transmission and configurations
2	Illustrate the various parameters and voltage gradients of transmission line conductors.
3	Learn the design requirements of EHV AC and DC lines
4	Understand the calculation of electrostatic field of AC lines

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Describe the types of power transmission and configurations
CO2	Model the transmission lines and estimate the voltage gradients and losses
CO3	Design EHV AC and DC transmission lines
CO4	Analyse the electrostatic field of AC lines

UNIT I	INTRODUCTION	9

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

UNIT II	CALCULATION OF LINE PARAMETERS	9

Calculation of resistance, inductance and capacitance for multi-conductor lines – calculation of sequence inductances and capacitances – line parameters for different modes of propagation – resistance and inductance of ground return, numerical example involving a typical 400/220kV line using line constant program.

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UNIT III	VOLTAGE GRADIENTS OF CONDUCTORS	9
Charge-potential relations for multi-conductor lines – surface voltage gradient on conductors – gradient factors and their use – distribution of voltage gradient on sub conductors of bundle - voltage gradients on conductors in the presence of ground wires on towers.		
UNIT IV	**CORONA EFFECTS**	**9**
Power losses and audible losses: I^2R loss and corona loss - audible noise generation and characteristics - limits for audible noise - Day-Night equivalent noise level- radio interference: corona pulse generation and properties - limits for radio interference fields.		
UNIT V	**ELECTROSTATIC FIELD OF EHV LINES**	**9**
Effect of EHV line on heavy vehicles - calculation of electrostatic field of AC lines- effect of high field on humans, animals, and plants - measurement of electrostatic fields - electrostatic Induction in unenergised circuit of a D/C line - induced voltages in insulated ground wires - electromagnetic interference.		

Reference (s)

1	Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, Second Edition, New Age International Pvt. Ltd., 2014.
2	Power Engineer’s Handbook, Revised and Enlarged 6th Edition, TNEB Engineers’ Association, October 2002.
3	Microtran Power System Analysis Corporation, Microtran Reference Manual, Vancouver Canada. (Website: www.microtran.com).

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE007T	ELECTRICAL TRANSIENTS IN POWER SYSTEMS	3	0	0	3

Prerequisite Course (s)

Advanced Power System Analysis

Course Objective (s):

The purpose of learning this course is to:

1	Expose the students to study about the Electromagnetic transient assessments of power systems.
2	Analyse the transient problems in power networks and components and the EMTP is a powerful tool used worldwide for the computer simulation of transients in power systems.
3	Learn the concepts of physical aspects of the electromagnetic transient phenomena and also broadens the computational treatment of transients
4	Acquire the knowledge of transient problems on electric utility and industrial power systems
5	Perform insulation co-ordination as applied to power system components.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Describe the formation and characteristics of travelling waves in transmission line
CO2	Apply the ATP/EMTP software for transient studies
CO3	Explain the various sources of electromagnetic transient.
CO4	Model power apparatus under transient conditions
CO5	Apply insulation co-ordination principles.

UNIT I	TRAVELLING WAVES ON TRANSMISSION LINE	9
Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion – Multi-conductor system and Velocity wave.		
UNIT II	**COMPUTATION OF POWER SYSTEM TRANSIENTS**	**9**
Principle of digital computation – Matrix method of solution, Modal analysis, Z transforms, Computation using EMTP – Simulation of switches and non-linear elements.		
UNIT III	**LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES**	**9**
Lightning: Physical phenomena of lightning – Interaction between lightning and power system – Factors contributing to line design – Switching: Short line or kilometric fault – Energizing transients - closing and re-closing of lines - line dropping, load rejection - Voltage induced by fault – Very Fast Transient Overvoltage (VFTO)		
UNIT IV	**BEHAVIOUR OF WINDING UNDER TRANSIENT CONDITION**	**9**
Initial and Final voltage distribution - Winding oscillation - travelling wave solution - Behaviour of the transformer core under surge condition – Rotating machine – Surge in generator and motor.		
UNIT V	**INSULATION CO-ORDINATION**	**9**
Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated Substation (GIS), insulation level, statistical approach, co-ordination between insulation and protection level – overvoltage protective devices – lightning arresters, substation earthing.		

Reference (s)

1	Pritindra Chowdhari, "Electromagnetic transients in Power System", John Wiley and Sons Inc., 2003.
2	Allan Greenwood, "Electrical Transients in Power System", Wiley & Sons Inc. New York,1991.
3	Klaus Ragaller, "Surges in High Voltage Networks", Plenum Press, New York, 2008
4	Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", (Second edition) Newage International (P) Ltd., New Delhi, 2014
5	Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2007.
6	IEEE Guide for safety in AC substation grounding IEEE Standard 80-2000.
7	Working Group 33/13-09 (1988), 'Very fast transient phenomena associated with Gas Insulated System', CIGRE, 33-13, pp. 1-20.

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Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE008T	ENERGY MANAGEMENT AND AUDITING	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):
The purpose of learning this course is to:

1	Expose the students to study the energy management techniques and auditing process.
2	Analyse the economical value cost and load management techniques.
3	Implement the energy management techniques in electrical equipment's.
4	Learn the concepts of metering for energy management.
5	Acquire the basic knowledge of lighting system and cogeneration.

Course Outcome (s) (COs):
At the end of this course, learners will be able to:

CO1	Apply the designing concepts and starting an energy management program for monitoring energy audit process.
CO2	Determine the Important concepts in an economic analysis, utility rate structures, cost of electricity, loss evaluation and implement load management technique.
CO3	Understanding the energy management technique for electrical equipment's.
CO4	Understanding the concept of various metering techniques for energy managements.
CO5	Understanding the various lighting schemes and cogeneration techniques.

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UNIT I	INTRODUCTION	9
Need for energy management – energy basics – designing and starting an energy management program – energy accounting – energy monitoring, targeting and reporting- energy audit process.		
UNIT II	**ENERGY COST AND LOAD MANAGEMENT**	**9**
Important concepts in an economic analysis – economic models – time value of money –utility rate structures – cost of electricity – loss evaluation. Load management: demand control techniques – utility monitoring and control system-HVAC and energy management – economic justification.		
UNIT III	**ENERGY MANAGEMENT FOR MOTORS, SYSTEMS, AND ELECTRICAL EQUIPMENTS**	**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	**LIGHTING SYSTEMS AND 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.		

Reference (s)	
1	Eastop T.D and Croft D.R, "Energy Efficiency for Engineers and Technologists", Logman Scientific & Technical, 1996.
2	Reay D.A., "Industrial Energy Conservation", first edition, Pergamon Press, 1979.
3	IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.
4	Amit K. Tyagi, "Handbook on Energy Audits and Management", TERI, 2003.
5	Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, "Guide to Energy Management", Fifth Edition, The Fairmont Press, Inc., 2011.

Regulation 2019		Semester II	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE009T	POWER DISTRIBUTION SYSTEMS	3	0	0	3

Prerequisite Course (s)

Advanced Power System Operation and Control

Course Objective (s):

The purpose of learning this course is to:

1	Understand design of substations
2	Understand the standards and Terminologies used in Distribution systems.
3	Analyse the modelling of loads and their characteristics
4	Analyse the design considerations of Primary and secondary distribution feeders.
5	Understand the Distribution system Performance and Control

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Explain various activities involved in distribution system planning.
CO2	Explain various components of the power distribution system.
CO3	Explain the fundamental features of grid management, load scheduling and load balancing.
CO4	Acquire In depth Knowledge on Distribution feeders and transformers
CO5	Acquire In depth Knowledge on Distribution Automation and Control

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UNIT I	DISTRIBUTION SYSTEM PLANNING AND DESIGN	9
Distribution system planning Short term planning, Long term planning, dynamic planning, Sub-transmission and substation design. Sub-transmission networks configurations, Substation bus schemes, Distribution substations ratings, Service areas calculations, Substation application curves.		
UNIT II	**DISTRIBUTED GENERATION SYSTEMS**	**9**
Distributed Generation Standards, DG potential, Definitions and terminologies; current status and future trends, Technical and economical impacts of DG Technologies, DG from renewable energy sources, DG from non-renewable energy sources.		
UNIT III	**DISTRIBUTED GENERATION EVALUATION**	**9**
Distributed generation applications, Operating Modes, Base load; peaking; peak shaving and emergency power, Isolated, momentary parallel and grid connection.		
UNIT IV	**DISTRIBUTION SYSTEM RELIABILITY ANALYSIS**	**9**
Primary and secondary system design considerations Primary circuit configurations, Primary feeder loading, secondary networks design Economic design of secondary's, Unbalance loads and voltage considerations.		
UNIT V	**DISTRIBUTION SYSTEM AUTOMATION AND CONTROL**	**9**
Distribution system performance and operation Distribution automation and control, Voltage drop calculation for distribution networks, Power loss Calculation, Application of capacitors to distribution systems, Application of voltage regulators to distribution systems.		

Reference (s)

1	Anthony J. Pansini "Electrical Distribution Engineering", CRC Press, 2006.
2	H Lee Willis, "Distributed Power Generation Planning and Evaluation", CRC Press, 2000.
3	James A Momoh, "Electric Power Distribution Automation Protection and Control" CRC Press, 2007
4	S.Sivanagaraju and V.Sankar, "Electrical power distribution and Automation" DhanpatRai and Co.
5	ToranGonen, "Electrical power distribution system Engineering" Mc-Graw Hill book company.

Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE010T	ADVANCED POWER SYSTEM DYNAMICS	3	0	0	3

Prerequisite Course (s)

Power System Dynamics

Course Objective (s):

The purpose of learning this course is to:

1	To impart the knowledge on the mathematical models applied in dynamic response of transient stability.
2	Expose the students to study the generator excitation controls and speed governing system.
3	To make the students familiar with the concepts of dynamic modelling of a synchronous machine and subsynchronous resonance oscillations.
4	To learn the dynamic mechanisms behind angle and voltage stability problems in electrical power systems.
5	To understand the concepts of transient stability enhancement methods.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Analyze the mathematical models applied in dynamic response of transient stability in electrical power system.
CO2	To describe the modelling of excitation and speed governing system.
CO3	Ability to develop the dynamic modelling of a synchronous machine and to explain subsynchronous resonance oscillations.
CO4	Analyze the load aspects of voltage stability analysis.
CO5	Describe and analyze of transient stability enhancement methods.

UNIT I	TRANSIENT STABILITY ANALYSIS	9

Review of numerical integration methods: Euler and Fourth Order Runge-Kutta methods, Numerical stability and implicit methods, Simulation of Power System Dynamic response: Structure of Power system Model, Synchronous machine representation: equations of motion, rotor circuit equations, stator voltage equations, Thevenin's and Norton's equivalent circuits, Excitation system representation, Transmission network and load representation, Overall system equations and their solution: Partitioned – Explicit and Simultaneous-implicit approaches, treatment of discontinuities, Simplified Transient Stability Simulation using implicit integration method.

UNIT II	SUBSYNCHRONOUS OSCILLATIONS	9
Introduction – Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters.		
UNIT III	SUBSYSNCHRONOUS RESONANCE (SSR)	9
Subsysnchronous Resonance (SSR): Characteristics of series –Compensated transmission systems – Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Analytical Methods – Numerical examples illustrating instability of subsynchronous oscillations – Impact of Network-Switching Disturbances: Steady-state switching – Successive network-Switching disturbances – Torsional Interaction Between Closely Coupled Units; time-domain simulation of subsynchronous resonance – EMTP with detailed synchronous machine model		
UNIT IV	TRANSMISSION, GENERATION AND LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS	9
Review of transmission aspects – Generation Aspects: Review of synchronous machine theory – Voltage and frequency controllers – Limiting devices affecting voltage stability – Voltage-reactive power characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load Aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models		
UNIT V	ENHANCEMENT OF TRANSIENT STABILITY AND COUNTER MEASURES FOR SUB SYNCHRONOUS RESONANCE	9
Principle behind transient stability enhancement methods: high-speed fault clearing, reduction of transmission system reactance, regulated shunt compensation, dynamic braking, reactor switching, independent pole-operation of circuit-breakers, single-pole switching, fast-valving, high-speed excitation systems; NGH damper scheme.		

Reference (s)

1	P. Kundur, "Power System Stability and Control", McGraw-Hill, 2006.
2	H.W. Dommel and N.Sato, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS-91, pp, 1643-1650, July/August 1972.
3	AU Power Lab Laboratory Manuals, Anna University, pp : 7-1 to 7-12, May 2004.
4	T.V. Cutsem and C.Vournas, "Voltage Stability of Electric Power Systems", Kluwer publishers,2002
5	H. W. Dommel, EMTP THEORY BOOK, Microtran Power System Analysis Corporation, Second Edition, 1996

Regulation 2019		Semester III	Total Hours			45
Category	**Course Code**	**Course Name**	**Hours / Week**			**C**
			L	**T**	**P**	
E	19PPSE011T	SMART GRID	3	0	0	3

Prerequisite Course (s)

Advanced Power System Analysis

Course Objective (s):

The purpose of learning this course is to:

1	Understand the Basic Concepts of Smart grid and its Characteristics, Working Principle.
2	Outline the role of Automation in monitoring system.
3	Study about the Sensing and Measuring technologies using in Smart meter.
4	Analyze concepts of Information Systems and Control Method using in Smart Grid.
5	Illustrate the applications of Smart grid.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Extent the basic concepts of Smart grid, Working, New technologies and features of small grid in the context of Indian grid.
CO2	Explain the role of automation in monitoring system.
CO3	Interpret the concept of Sensing and Measuring methods, types of advanced Meters and Power electronics using in Smart grid.
CO4	Infer the concept of Information technologies, types of communication systems and control methods.
CO5	Distinguish the security problem in smart grid and various methods to solve the security problems in smart grid.

UNIT I	INTRODUCTION TO SMART GRID	9
Evolution of Electric Grid – Need for smart grid – Difference between conventional & smart grid – Overview of enabling technologies – International experience in smart grid deployment efforts – smart grid road map for INDIA – smart grid architecture		
UNIT II	**WIDE AREA MONITORING SYSTEM**	**9**
Fundamentals of synchrophasor technology – concept and benefits of wide area monitoring system – Structure and functions of Phasor Measuring Unit (PMU) and Phasor Data Concentrator (PDC) – Road Map for synchrophasor applications (NAPSI) – Operational experience and Blackout analysis using PMU		
UNIT III	**SMART METERS**	**9**
Features and functions of smart meters – Functional specification – category of smart meters – AMR and AMI drivers and benefits – AMI protocol – Demand Side Integration: Peak load, Outage and Power Quality management.		
UNIT IV	**INFORMATION AND COMMUNICATION TECHNOLOGY**	**9**
Overview of smart grid communication system – Modulation and Demodulation techniques: Radio communication – Mobile communication – Power line communication – Optical fibre communication – Communication protocol for smart grid.		
UNIT V	**SMART GRID APPLICATIONS**	**9**
Overview and concept of renewable integration – role of protective relaying in smart grid – House Area Network – Advanced Energy Storage Technology: Flow battery – Fuel cell – SMES – Super capacitors – Plug – in Hybrid electric Vehicles – Cyber Security requirements – Smart grid information model		

Reference (s)

1	"Smart Grid Technology and Applications" by Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Nick Jenkins, John Wiley & Sons Publication, 2012.
2	"Smart Grid Primer", Published by Power Grid Corporation of India Limited, September 2014.
3	"Smart grid – integrating renewable, distributed and efficient energy", Fereidoon.P.sioshansi, Academic Press, 2011.
4	"Smart Grids: Infrastructure, Technology and Solutions" Edited by Stuart Borlase, CRC Press Publication, 2013.

Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE012T	HIGH VOLTAGE DIRECT CURRENT TRANSMISSION	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):

The purpose of learning this course is to:

1	Understand the concept, planning of DC power transmission and comparison with AC Power transmission.
2	Understand the various HVDC converter circuits.
3	Study about the different HVDC system control.
4	Model and analysis the DC system under steady state.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Illustrate planning of DC power transmission and comparison with AC Power transmission.
CO2	Analyze various converters used in the HVDC system.
CO3	Summarize various control strategies associated with the HVDC system.
CO4	Design and analysis the DC system under steady state.

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UNIT I	DC POWER TRANSMISSION TECHNOLOGY	9
Introduction - Comparison of AC and DC transmission – Application of DC transmission – Description of DC transmission system - Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables, VSC based HVDC.		
UNIT II	**ANALYSIS OF HVDC CONVERTERS AND HVDC SYSTEM CONTROL**	**9**
Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters.General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering - power control – Higher level controllers.		
UNIT III	**MULTITERMINAL DC SYSTEMS**	**9**
Introduction – Potential applications of MTDC systems - Types of MTDC systems - Control and protection of MTDC systems - Study of MTDC systems.		
UNIT IV	**POWER FLOW ANALYSIS IN AC/DC SYSTEMS**	**9**
Per unit system for DC Quantities - Modelling of DC links - Solution of DC load flow - Solution of AC-DC power flow - Case studies.		
UNIT V	**SIMULATION OF HVDC SYSTEMS**	**9**
Introduction – System simulation: Philosophy and tools – HVDC system simulation – Modeling of HVDC systems for digital dynamic simulation – Dynamic intraction between DC and AC systems.		

Reference (s)

1	K.R.Padiyar, , "HVDC Power Transmission Systems", New Age International (P) Ltd., New Delhi, 2002.
2	J.Arrillaga, , "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983.
3	P. Kundur, "Power System Stability and Control", McGraw-Hill, 2006.
4	Erich Uhlmann, " Power Transmission by Direct Current", BS Publications, 2014.
5	V.K.Sood, HVDC and FACTS controllers – Applications of Static Converters in Power System, 2014 , Kluwer Academic Publishers.

Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE013T	INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN	3	0	0	3

Prerequisite Course (s)

Power System Dynamics

Course Objective (s):

The purpose of learning this course is to:

1	Understand the calculation used with induction motor starting
2	Study and calculate the ratings of capacitors for power factor correction
3	Understand and calculate harmonics indices in power quality
4	Design filters and to analyze the flicker
5	Introduce computer analysis methods for ground grid calculation

Course Outcome (s) (COs):

At thc cnd of this course, learners will be able to:

CO1	Solve problems in induction motor starting
CO2	Design a filters
CO3	Calculate power factor and correction of power factor
CO4	Perform computer aided harmonic and flicker analysis
CO5	Illustrate on various grid grounding methodologies

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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-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.		

Reference (s)

1	Ramasamy Natarajan, "Computer-Aided Power System Analysis", Marcel Dekker Inc., 2002.

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Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE014T	OPTIMAL CONTROL AND FILTERING	3	0	0	3

Prerequisite Course (s)

NIL

Course Objective (s):
The purpose of learning this course is to:

1	Understand the basic concepts of optimal control.
2	Learn concepts of LQ control and dynamic programming.
3	Analyse the numerical techniques for optimal control.
4	Acquire the basic knowledge in filtering and its estimations.
5	Understand the concepts of Kalman filter and its properties.

Course Outcome (s) (COs):
At the end of this course, learners will be able to:

CO1	Analyse the optimal control problem forms and necessary condition for optimal control.
CO2	Determine the LQ control problems and constraints for dynamic programming.
CO3	Apply the numerical techniques for optimal control.
CO4	Determine the basic concepts of filter through various types of estimations.
CO5	Apply Kalman filter and its property in stability problems.

UNIT I	INTRODUCTION	9
Statement of optimal control problem – Problem formulation and forms of optimal Control – Selection of performance measures. Necessary conditions for optimal control – Pontryagin's minimum principle – State inequality constraints – Minimum time problem.		
UNIT II	**LQ CONTROL PROBLEMS AND DYNAMIC PROGRAMMING**	**9**
Linear optimal regulator problem – Matrix Riccatti equation and solution method – Choice of weighting matrices – Steady state properties of optimal regulator – Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation.		
UNIT III	**NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL**	**9**
Numerical solution of 2-point boundary value problem by steepest descent and Fletcher Powell method solution of Ricatti equation by negative exponential and interactive Methods		
UNIT IV	**FILTERING AND ESTIMATION**	**9**
. Filtering – Linear system and estimation – System noise smoothing and prediction –Gauss Markov discrete time model – Estimation criteria – Minimum variance estimation – Least square estimation – Recursive estimation.		
UNIT V	**KALMAN FILTER AND PROPERTIES**	**9**
Filter problem and properties – Linear estimator property of Kalman Filter – Time invariance and asymptotic stability of filters – Time filtered estimates and signal to noise ratio improvement – Extended Kalman filter.		

Reference (s)	
1	KIRK D.E., 'Optimal Control Theory – An introduction', Prentice hall, N.J., 1995.
2	Sage, A.P., 'Optimum System Control', Prentice Hall N.H., 1977
3	Anderson, BD.O. and Moore J.B., 'Optimal Filtering', Prentice hall Inc., N.J., 2005
4	S.M. Bozic, "Digital and Kalman Filtering", Edward Arnould, London, 1994.
5	Astrom, K.J., "Introduction to Stochastic Control Theory", Academic Press, Inc, N.Y., 1970.

Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE015T	SOLAR AND ENERGY STORAGE SYSTEMS	3	0	0	3

Prerequisite Course (s)

Power Electronics Converters & Renewable Energy Resources

Course Objective (s):

The purpose of learning this course is to:

1	Acquire knowledge about the behaviour of solar panels for variation in different parameters.
2	To test and understand the behaviour and applications of solar panels.

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	To discuss about the basic characteristics of sunlight and solar cells
CO2	An ability to design a solar model in standalone system
CO3	To discuss about the grid connected PV system
CO4	An ability to design a storage system with relevant PV model
CO5	To discuss about the various applications of solar energy system

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UNIT I	INTRODUCTION	9
Characteristics of sunlight – semiconductors and P-N junctions –behavior of solar cells – cell properties – PV cell interconnection		
UNIT II	STAND ALONE PV SYSTEM	9
Solar modules – storage systems – power conditioning and regulation - protection – stand alone PV systems design – sizing		
UNIT III	GRID CONNECTED PV SYSTEMS	9
PV systems in buildings – design issues for central power stations – safety – Economic aspect – Efficiency and performance - International PV programs		
UNIT IV	ENERGY STORAGE SYSTEMS	9
Impact of intermittent generation – Battery energy storage – solar thermal energy storage – pumped hydroelectric energy storage		
UNIT V	APPLICATIONS	9
Water pumping – battery chargers – solar car – direct-drive applications –Space – Telecommunications.		

Reference (s)

1	Eduardo Lorenzo G. Araujo, Solar electricity engineering of photovoltaic systems, Progensa,2003.
2	Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, Applied Photovoltaics, 2012,Earthscan, UK.
3	Frank S. Barnes & Jonah G. Levine, Large Energy storage Systems Handbook , CRC Press, 2011.
4	Solar & Wind Energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern, 1990
5	Solar Energy – S.P. Sukhatme, Tata McGraw Hill,1987.

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Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE016T	OPTIMIZATION TECHNIQUES	3	0	0	3

Prerequisite Course (s)
Applied Mathematics for Electrical Engineers

Course Objective (s):
The purpose of learning this course is to:

1	Acquire knowledge in different optimization techniques.
2	Analyse the mathematical model using linear technique.
3	Analyse the non linear function using non linear programming.
4	Analyse the multistage problem using dynamic programming
5	Analyse the constrained and unconstrained problems.

Course Outcome (s) (COs):
At the end of this course, learners will be able to:

CO1	Understand and analyse the basic concepts of optimization techniques
CO2	Understand the linear problems using various methods.
CO3	Understand analyse the nonlinear function using non linear programming.
CO4	To solve the multistage problems using different dynamic programming
CO5	Understand and analyse the basic concepts of genetic algorithm.

UNIT I	INTRODUCTION	9
Definition, Classification of optimization problems, Classical Optimization Techniques, Single and Multiple Optimization with and without inequality constraints.		
UNIT II	LINEAR PROGRAMMING (LP)	9
Simplex method of solving LPP, revised simplex method, duality, Constrained optimization, Theorems and procedure, Linear programming, mathematical model, solution technique, duality.		
UNIT III	NON LINEAR PROGRAMMING	9
Steepest descent method, conjugates gradient method, Newton"s Method, Sequential quadratic programming, Penalty function method, augmented Lagrange multiplier method.		
UNIT IV	DYNAMIC PROGRAMMING (DP)	9
Multistage decision processes, concept of sub-optimization and principle of optimality, Recursive relations, Integer Linear programming, Branch and bound algorithm.		
UNIT V	GENETIC ALGORITHM	9
Introduction to genetic Algorithm, working principle, coding of variables, fitness function, GA operators; Similarities and differences between Gas and traditional methods; Unconstrained and constrained optimization using genetic Algorithm, real coded gas, Advanced Gas, global optimization using GA, Applications to power system.		

Reference (s)

1	Computational methods in Optimization, Polak , Academic Press,1971.
2	Optimization Theory with applications, Pierre D.A., Wiley Publications,1969.
3	Taha, H. A., Operations Research: An Introduction, Seventh Edition, Pearson Education Edition, Asia, New Delhi ,2002.
4	S.S. Rao,"Optimization – Theory and Applications", Wiley-Eastern Limited, 1992.
5	G.Luenberger," Introduction of Linear and Non-Linear Programming" , Wesley Publishing Company, 2011

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Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE017T	POWER SYSTEM STABILITY	3	0	0	3

Prerequisite Course (s)

Advanced Power System Analysis

Course Objective (s):
The purpose of learning this course is to:

1	Basic concepts on power stability consideration and its classification
2	Understand various methods of transient stability for excitation system and governors
3	Understand state space models for small signals
4	Understand various aspects in voltage stability
5	Find the stability improvement for power system enhancement

Course Outcome (s) (COs):
At the end of this course, learners will be able to:

CO1	Understand the modelling of power system stability
CO2	Find the transient stability using different method
CO3	Analysis the small signal stability by state space model
CO4	Illustrate voltage stability for generation, transmission and load aspects
CO5	Apply the different stability improvement system

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UNIT I	INTRODUCTION TO STABILITY	9
Power system stability considerations – definitions-classification of stability-rotor angle and voltage stability-synchronous machine representation –classical model-load modeling concepts-modeling of excitation systems-modeling of prime movers.		
UNIT II	**TRANISIENT STABILITY**	**9**
Transient stability-swing equation-equal area criterion-solution of swing equation-Numerical methods -Euler method-Runge-Kutte method-critical clearing time and angle-effect of excitation system and governors-Multimachine stability –extended equal area criterion-transient energy function approach.		
UNIT III	**SMALL SIGNAL STABIITY**	**9**
Small signal stability – state space representation – eigen values- modal matrices-small signal stability of single machine infinite bus system – synchronous machine classical model representation-effect of field circuit dynamics-effect of excitation system-small signal stability of multimachine system.		
UNIT IV	**VOLTAGE STABILITY**	**9**
Voltage stability – generation aspects - transmission system aspects – load aspects – PV curve – QV curve – PQ curve – analysis with static loads – loadability limit - sensitivity analysis-continuation power flow analysis - instability mechanisms-examples		
UNIT V	**STABILITY IMPROVEMENT**	**9**
Methods of improving stability – transient stability enhancement – high speed fault clearing – steam turbine fast valving-high speed excitation systems- small signal stability enhancement-power system stabilizers – voltage stability enhancement – reactive power control.		

Reference (s)	
1	Kundur, P.Power System Stability and Control", McGraw-Hill International Editions, 2006.
2	Anderson, P.M. and Fouad, A.A., „Power System Control and Stability", Galgotia Publications, New Delhi, 2008.
3	Van Cutsem, T. and Vournas, C., "Voltage Stability of Electric Power Systems", Kluwer Academic Publishers, 2002.

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Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE018T	WIND ENERGY CONVERSION SYSTEMS	3	0	0	3

Prerequisite Course (s)
Power Electronics Application to Power Systems

Course Objective (s): The purpose of learning this course is to:	
1	Understand Components of WECS-WECS schemes
2	Gain knowledge on wind turbine
3	Gain knowledge on Constant speed constant frequency systems
4	Gain knowledge on Variable speed constant frequency systems
5	Gain knowledge on grid connected systems

Course Outcome (s) (COs): At the end of this course, learners will be able to:	
CO1	Understand the different non conventional sources and the power generation techniques to generate electrical
CO2	Design a prescribed engineering sub-system
CO3	Recognize the need and ability to engage in lifelong learning for further developments in this field
CO4	Apply engineering materials in renewable Energy/ power generation.
CO5	Design grid connected and standalone solar systems.

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UNIT I	INTRODUCTION	9
Components of WECS-WECS schemes-Power obtained from wind-simple momentum theory-Power coefficient-Sabinin's theory-Aerodynamics of Wind turbine		
UNIT II	**WIND TURBINES**	**9**
HAWT-VAWT-Power developed-Thrust-Efficiency-Rotor selection-Rotor design considerations-Tip speed ratio-No. of Blades-Blade profile-Power Regulation-yaw control-Pitch angle control-stall control-Schemes for maximum power extraction.		
UNIT III	**FIXED SPEED SYSTEMS**	**9**
Generating Systems- Constant speed constant frequency systems -Choice of Generators-Deciding factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed-Model wind turbine rotor - Drive Train model-Generator model for Steady state and Transient stability analysis.		
UNIT IV	**VARIABLE SPEED SYSTEMS**	**9**
Need of variable speed systems-Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG -Variable speed generators modeling - Variable speed variable frequency schemes.		
UNIT V	**GRID CONNECTED SYSTEMS**	**9**
Stand alone and Grid Connected WECS system-Grid connection Issues-Machine side & Grid side controllers-WECS in various countries		

References:	
1	L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990
2	Ion Boldea, "Variable speed generators", Taylor & Francis group, 2015.
3	E.W.Golding "The generation of Electricity by wind power", Redwood burn Ltd., Trowbridge,2001.
4	S.Heir "Grid Integration of WECS", Wiley 2011.
5	Non-Conventional Sources of Energy by: G.D. Rai, Khanna Publishers.

Regulation 2019		Semester III	Total Hours			45
Category	Course Code	Course Name	Hours / Week			C
			L	T	P	
E	19PPSE019T	POWER SYSTEM PROTECTION	3	0	0	3

Prerequisite Course (s)

Advanced Power System Analysis

Course Objective (s):

The purpose of learning this course is to:

1	Understand the various protection schemes available for transformer and Generator Protection
2	Impart knowledge on over current protection schemes
3	Understand the concept of distance and carrier protection of transmission lines
4	Introduce the various protection schemes available for Bus bar protection
5	Understand the working principle of Numerical relay and its applications

Course Outcome (s) (COs):

At the end of this course, learners will be able to:

CO1	Choose a suitable protection schemes for various transformer and generator faults.
CO2	Explain the various overcurrent protection schemes available for feeder protection
CO3	Explain the necessity of distance and carrier protection of transmission lines.
CO4	Apply the suitable protective schemes for bus bar faults.
CO5	Apply the suitable numerical relay protection scheme for various power system equipments

UNIT I	EQUIPMENT PROTECTION	9

Types of transformers – Phasor diagram for a three – Phase transformer-Equivalent circuit of transformer – Types of faults in transformers- Over – current protection Percentage Differential Protection of Transformers - Inrush phenomenon-High resistance Ground Faults in Transformers - Inter-turn faults in transformers - Incipient faults in transformers - Phenomenon of over-fluxing in transformers - Transformer protection application chart .Electrical circuit of the generator –Various faults and abnormal operating conditions-rotor fault –Abnormal operating conditions; numerical examples for typical transformer and generator protection schemes.

UNIT II	OVER CURRENT PROTECTION	9

Time – Current characteristics-Current setting – Time setting-Over current protective schemes - Reverse power or directional relay - Protection of parallel feeders - Protection of ring feeders - Earth fault and phase fault protection - Combined Earth fault and phase fault protection scheme - Phase fault protective scheme directional earth fault relay - Static over current relays; numerical example for a radial feeder.

UNIT III	DISTANCE AND CARRIER PROTECTION OF TRANSMISSION LINES	9

Drawback of Over current protection – Introduction to distance relay – Construction and working principle of impedance relay – Reactance relay – Mho relay. Comparison of relays.

UNIT IV	BUSBAR PROTECTION	9

Introduction – Differential protection of busbars-external and internal fault - Actual behaviors of a protective CT - Circuit model of a saturated CT - External fault with one CT saturation : need for high impedance – Minimum internal fault that can be detected by the high – Stability ratio of high impedance busbar differential scheme - Supervisory relay-protection of three phase busbars-Numerical examples on design of high impedance busbar differential scheme.

UNIT V	NUMERICAL PROTECTION	9

Introduction – Block diagram of numerical relay - Sampling theorem- Correlation with a reference wave – Least error squared (LES) technique - Digital filtering- numerical over current protection – Numerical transformer differential protection-Numerical distance protection of transmission line. Introduction to synchrophasor technology, phasor measurement unit – Blockout study in India using PMU.

References:

1	Y.G. Paithankar and S.R Bhide, "Fundamentals of Power System Protection", Prentice-Hall of India, 2003.
2	P.Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
3	Badri Ram and D.N. Vishwakarma, "Power System Protection and Switchgear", Tata McGraw- Hill Publishing Company, 2002.