ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

REGULATIONS – 2015

CHOICE BASED CREDIT SYSTEM

M.E.POWER ENGINEERING AND MANAGEMENT

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

I. To prepare the students to have career in the electrical power industry/research organization/teaching.
II. To provide good foundation in mathematics, management and computational technology to analyze and solve problems encountered in electrical power industry.
III. Pursue lifelong learning and continuous improvement of their knowledge in the electrical power industry.
IV. To understand the national and global issues related to the electrical power industry and to be considerate of the impact of these issues on the environment and within different cultures.
V. To apply engineering principles to assess and evaluate renewable energy systems for maximum performance.
VI. To provide the students with knowledge to be involved with the technology advancements and future developments in power generation, and management as well as with alternate and new energy resources.

PROGRAMME OUTCOMES (POs):

On successful completion of the Programme,

1. Be able to modify or propose a new process design to increase energy efficiency and reduce environmental impacts.
2. Be able to apply their knowledge of power generation and management to new applications in electrical power utility/industry.
3. Be able to perform, analyze, and apply the results of experiments to Electrical power application improvements.
4. Be able to look at all options in design and development projects and choose the most appropriate option for the current project.
5. Have the ability to function effectively as a member of a project team to deal the technical challenges in power utility.
6. Be able to identify problems in electrical power systems, analyze the problems, and solve them using all of the required and available resources.
7. Be able to effectively communicate technical project information in writing or in personal presentation and conversation.
8. Be engaged in continuously learning the new practices, principles, and techniques of the electrical power industry.
9. Be able to manage power quality issues in Macro/Micro Grid as well as Smart Grid.
10. Ability to work on application software packages for modern power system planning and design and operation.

Program Educational Objective	Program Outcome									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	✓	✓	✓	✓	✓			✓	✓	✓
III								✓		
IV	✓		✓	✓		✓			✓	✓
V					✓		✓	✓	✓	✓
VI	✓	✓	✓	✓		✓		✓	✓	✓

Attested

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Anna University, Chennai-600 025.

			PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
YEAR 1	SEM 1	Distribution Systems Management and Automation	✓	✓	✓	✓					✓	
		Advanced Power System Analysis	✓	✓	✓			✓				✓
		Power Business Management	✓	✓			✓	✓		✓		✓
		Renewable Energy Technology	✓		✓	✓			✓			
		Applied Mathematics for Electrical Engineers			✓							
		Elective I										
		Power Engineering Laboratory					✓			✓	✓	✓
	SEM 2	Restructured Power System	✓	✓		✓			✓			
		Grid Integration of Renewable Energy Sources	✓		✓	✓		✓		✓	✓	
		SCADA System and Applications Management	✓	✓	✓			✓		✓		
		Smart Grids	✓						✓		✓	
		Elective II										
		Elective III										
		Energy Laboratory					✓	✓		✓	✓	

		Technical Seminar							✓	✓		✓
YEAR 2	**SEM 3**	Energy Management and Auditing	✓	✓			✓	✓		✓		
		Elective IV										
		Elective V										
		Project Work Phase I							✓	✓		✓
	SEM 4	Project Work Phase II							✓	✓		✓

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REGULATIONS – 2015
CHOICE BASED CREDIT SYSTEM
M.E. POWER ENGINEERING AND MANAGEMENT
CURRICULA AND SYLLABI I TO IV SEMESTERS

SEMESTER - I

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA7156	Applied Mathematics for Electrical Engineers	FC	4	4	0	0	4
2.	PS7151	Advanced Power System Analysis	PC	4	4	0	0	4
3.	PW7101	Power Business Management	PC	3	3	0	0	3
4.	PW7151	Distribution Systems Management and Automation	PC	3	3	0	0	3
5.	PW7152	Renewable Energy Technology	PC	3	3	0	0	3
6.		Elective I	PE	3	3	0	0	3
PRACTICALS								
7.	PW7111	Power Engineering Laboratory	PC	4	0	0	4	2
			TOTAL	**24**	**20**	**0**	**4**	**22**

SEMESTER - II

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PS7254	Restructured Power System	PC	3	3	0	0	3
2.	PS7255	Smart Grids	PC	3	3	0	0	3
3.	PW7201	Grid Integration of Renewable Energy Sources	PC	3	3	0	0	3
4.	PW7251	SCADA System and Applications Management	PC	3	3	0	0	3
5.		Elective II	PE	3	3	0	0	3
6.		Elective III	PE	3	3	0	0	3
PRACTICALS								
7.	PW7211	Energy Laboratory	PC	4	0	0	4	2
8.	PW7212	Technical Seminar	EEC	2	0	0	2	1
			TOTAL	**24**	**18**	**0**	**6**	**21**

SEMESTER - III

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PW7351	Energy Management and Auditing	PC	3	3	0	0	3
2.		Elective IV	PE	3	3	0	0	3
3.		Elective V	PE	3	3	0	0	3
PRACTICALS								
4.	PW7311	Project Work Phase I	EEC	12	0	0	12	6
			TOTAL	**21**	**9**	**0**	**12**	**15**

SEMESTER - IV

Sl. No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
PRACTICALS								
1.	PW7411	Project Work Phase II	EEC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

TOTAL NO. OF CREDITS: 70

FOUNDATION COURSES (FC)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.		Applied Mathematics for Electrical Engineers	FC	4	4	0	0	4

PROFESSIONAL CORE (PC)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.		Distribution Systems Management and Automation	PC	3	3	0	0	3
2.		Advanced Power System Analysis	PC	4	4	0	0	4
3.		Power Business Management	PC	3	3	0	0	3
4.		Renewable Energy Technology	PC	3	3	0	0	3
5.		Power Engineering Laboratory	PC	4	0	0	4	2
6.		Restructured Power System	PC	3	3	0	0	3
7.		Grid Integration of Renewable Energy Sources	PC	3	3	0	0	3
8.		SCADA System and Applications Management	PC	3	3	0	0	3
9.		Smart Grids	PC	3	3	0	0	3
10.		Energy Laboratory	PC	4	0	0	4	2
11.		Energy Management and Auditing	PC	3	3	0	0	3

PROFESSIONAL ELECTIVES (PE)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	PW7072	Electric Vehicles and Power Management	PE	3	3	0	0	3
2.	PW7071	Climate Change and Energy Environment	PE	3	3	0	0	3
3.	PW7074	Energy Economics, Financing, Regulation and Energy Modeling	PE	3	3	0	0	3
4.	PW7002	Energy Systems Modeling and Analysis	PE	3	3	0	0	3
5.	PW7075	Sustainable Energy Utilization	PE	3	3	0	0	3
6.	PE7152	Analysis of Electrical Machines	PE	3	3	0	0	3
7.	CO7152	Soft Computing Techniques	PE	3	3	0	0	3
8.	PS7071	Distributed Generation and Micro Grid	PE	3	3	0	0	3
9.	PW7001	Energy Efficient Buildings	PE	3	3	0	0	3
10.	PW7003	Governance and Management of Natural Resources	PE	3	3	0	0	3
11.	PW7076	Urban and Rural Energy Management	PE	3	3	0	0	3
12.	PE7073	Power Quality	PE	3	3	0	0	3
13.	PE7252	Modelling and Design of SMPS	PE	3	3	0	0	3
14.	PS7253	Flexible AC Transmission Systems	PE	3	3	0	0	3
15.	PW7073	Electricity Market Analysis	PE	3	3	0	0	3
16.	PS7251	Advanced Power System Protection	PE	3	3	0	0	3

17.	PS7152	Power System Dynamics	PE	3	3	0	0	3
18.	HV7073	Electromagnetic Interference and Compatibility	PE	3	3	0	0	3
19.	PW7004	Integrated Energy Systems	PE	3	3	0	0	3
20.	ET7074	MEMS Technology	PE	3	3	0	0	3
21.	HV7072	Design of Substations	PE	3	3	0	0	3
22.	PS7073	Optimisation Techniques	PE	3	3	0	0	3
23.	PS7075	Wind Energy Conversion System	PE	3	3	0	0	3
24.	PS7072	High Voltage Direct Current Transmission	PE	3	3	0	0	3
25.	PE7072	Power Electronics for Renewable Energy Systems	PE	3	3	0	0	3
26.	CO7071	Control of Electrical Drives	PE	3	3	0	0	3
27.	PS7074	Solar and Energy Storage System	PE	3	3	0	0	3

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.		Technical Seminar	EEC	2	0	0	2	1
2.		Project Work Phase I	EEC	12	0	0	12	6
3.		Project Work Phase II	EEC	24	0	0	24	12

Attested

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MA7156 APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS **LT P C**
4 0 0 4

OBJECTIVES:

- To develop the ability to apply the concepts of Matrix theory and Linear programming in Electrical Engineering problems.
- To achieve an understanding of the basic concepts of one dimensional random variables and apply in electrical engineering problems.
- To familiarize the students in calculus of variations and solve problems using Fourier transforms associated with engineering applications..

UNIT I MATRIX THEORY **12**

The Cholesky decomposition - Generalized Eigen vectors, Canonical basis - QR factorization - Least squares method - Singular value decomposition

UNIT II CALCULUS OF VARIATIONS **12**

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

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 – Function of a Random Variable

UNIT IV LINEAR PROGRAMMING **12**

Formulation – Graphical solution – Simplex method – Two phase method - Transportation and Assignment Models

UNIT V FOURIER SERIES **12**

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

TOTAL: 60 PERIODS

BOOKS FOR STUDY:

1. Richard Bronson, "Matrix Operation", Schaum's outline series, 2nd Edition, McGraw Hill, 2011.
2. Gupta, A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi, 1997.
3. Oliver C. Ibe, "Fundamentals of Applied Probability and Random Processes, Academic Press, (An imprint of Elsevier), 2010.
4. Taha, H.A., "Operations Research, An introduction", 10th edition, Pearson education, New Delhi, 2010.

5. Andrews L.C. and Phillips R.L., Mathematical Techniques for Engineers and Scientists, Prentice Hall of India Pvt.Ltd., New Delhi, 2005.

REFERENCES

1. Elsgolts, L., Differential Equations and the Calculus of Variations, MIR Publishers, Moscow, 1973.
2. Grewal, B.S., Higher Engineering Mathematics, 42nd edition, Khanna Publishers, 2012.
3. O'Neil, P.V., Advanced Engineering Mathematics, Thomson Asia Pvt. Ltd., Singapore, 2003.
4. Johnson R. A. and Gupta C. B., "Miller & Freund's Probability and Statistics for Engineers", Pearson Education, Asia, 7th Edition, 2007.

PS7151 ADVANCED POWER SYSTEM ANALYSIS **L T P C**
4 0 0 4

COURSE OBJECTIVES

- To introduce different techniques of dealing with sparse matrix for large scale power systems.
- To impart in-depth knowledge on different methods of power flow solutions.
- To perform optimal power flow solutions in detail.
- To perform short circuit fault analysis and understand the consequence of different type of faults.

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 Bi-factorization and Gauss elimination methods; Repeat solution using Left and Right factors and L and U matrices.

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, Continuation of power flow.

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**

Formation of bus impedance matrix with mutual coupling (single phase basis and three phase basis) - 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 – symmetrical and unsymmetrical faults.

UNIT V DISTRIBUTION LOAD FLOW 12

Need for distribution load flow-Forward, Backward Sweep method – Iterative distribution load flow -3-phase load flow- distributed generation.

TOTAL: 60 PERIODS

OUTCOME

- Learners are equipped with the power system studies that needed for the transmission system planning.
- Learners will be able to analyse the impact of distributed generators on the performance of distribution system

TEXTBOOKS

1. G W Stagg , A.H El. Abiad "Computer Methods in Power System Analysis", M cGraw Hill, 1968.
2. P.Kundur, "Power System Stability and Control", McGraw Hill, 1994.

REFERENCES:

1. A.J.Wood and B.F.Wollenberg,"Power Generation Operation and Control", John Wiley and sons, New York, 1996.
2. W.F.Tinney and W.S.Meyer, "Solution of Large Sparse System by Ordered Triangular Factorization" IEEE Trans. on Automatic Control, Vol : AC-18, pp:333-346, Aug 1973.
3. K.Zollenkopf, "Bi-Factorization: Basic Computational Algorithm and Programming Techniques ; pp:75-96 ; Book on "Large Sparse Set of Linear Systems" Editor: J.K.Rerd,Academic Press, 1971.
4. M.A.Pai," Computer Techniques in Power System Analysis",Tata McGraw-Hill Publishing Company Limited, New Delhi, 2006
5. D. Thukara,H.M. Wijekoon Banda & Jovitha Jerome, 'A robust three phase power flow algorithm for radial distribution systems' ,Electric Power Systems Research 50 (1999) 227–236

PW7101 POWER BUSINESS MANGEMENT L T P C

3 0 0 3

COURSE OBJECTIVE:

- To understand the power scenario in india
- To understand the electricity acts and regulatory commission policies
- To provide knowledge about transmission and distribution management, tariff policies and power purchase agreement

UNIT I POWER MANAGEMENT IN INDIA 9

Growth of Power Industry in India, Organizational Structure of central and state companies and its major roles and regulations, Power scenario in India, Load management in power sector, Grid Management, Development of power projects in India vs. demand study, Management of Electricity Demand Scenario in state and overall India, Energy Management System, Energy conservation & Efficiency measures. **Case Study**: Power demand study in state, Load management study in state

UNIT II ACT AND REGULATORY COMMISSIONS 9

Introduction to the Power Scenario, Overview of the Indian Electricity Act 1910, Electricity Supply Act1948, Electricity Regulatory Commissions Act 1998, Energy Conservation Act 2001, The Electricity Act 2003, State Electricity Regulatory commission(SERC),Central Electricity Regulatory commission (CERC), Tribunal, Electricity regulatory and Industry Structure in India

UNIT III TRANSMSISION AND DISTRIBUTION MANAGEMENT 9

General Concept of Power System, AC Transmission, FACTS, HVDC Transmission, Major Equipment & Accessories Power Transmission Network in the Indian Scenario,(Exchange of Energy between interconnected Systems), Electricity Grid Code, Distribution System, Commercial Operations of a Distribution Utility , Metering & Billing, Revenue Collection, Emerging Trends in Metering Technology, Available Transfer Capability losses and remedial measures.

UNIT IV TARIFF POLICY AND DETERMINATION OF TARIFF 9

Tariff policy, Tariff regulations, Tariff structure ,fixed tariff, availability based tariff, time of the day tariff, Multi Year Tariff, Assessment of tariff levels, Determination of tariff for Generation, transmission and distribution levels, Comparison of year wise tariff/ state wise.
Case Study: Present tariff Scenario in tamilnadu and compare with other states.

UNIT V POWER PURCHASE MANAGEMENT 9

Scope of the power purchase management, Definition and interpretation of terms of a model power purchase agreement (PPA), Desirable Principles of power purchase agreements, Requirements of PPA, Risks and responsibilities in a power purchase agreement, Negotiating Power purchase agreements, PPA - Financial and legal issues, Drafting of a model PPA.

Case Study: Study and Analysis of a sample PPA between a Generation and Distribution Utility, Financial Statement Analysis of a State Power Sector Organization, Power Project Appraisal, Returns of a large Power Project etc.

TOTAL: 45 PERIODS

OUTCOME:

- The students will have ideas on the present scenario of indian electricity industry and also the hierarchy of its structure, acts and policies.

REFERENCES:

1. Turan Goneu, Electric Power Distribution System Engg , McGraw Hill company
2. Leon K. Kirchmayer, Economic Operation of Power Systems Publisher by Wiley Eastern Ltd.
3. Terms and Conditions of Tariff –CERC Regulations
4. Energy Pricing in India by Herry Sarkar and Gopal K. Kadekodi – Publisher - United National Development Program & Economic Commission for Asia & Pacific
5. Indian Electricity Act, 1910
6. Indian Electricity (Supply) Act, 1948
7. Electricity Act 2003
8. Central Regulatory Commission Act, 1998
9. Energy Conservation Act 2001
10. Governing Power by S.L . Rao, TERI Publication

PW7151 DISTRIBUTION SYSTEMS MANAGEMENT AND AUTOMATION **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To provide knowledge about management of distribution system and distribution automation
- To gain knowledge about planning and designing of distribution system
- To analyze power quality in distribution system

UNIT I INTRODUCTION 9

Overview of the distribution system, Importance of Distribution Systems, the Differences of Power Supply between Urban and Rural Area, Distribution system Consumer Classification

UNIT II DISTRIBUTION SYSTEM PLANNING 9

Factors effecting planning, present techniques, planning models(Short term planning, long term planning and dynamic planning), planning in the future, future nature of distribution planning, Role of computer in Distribution planning. Load forecast, Load characteristics and Load models.

UNIT III DISTRIBUTION SYSTEM DESIGN 9

Types of sub- transmission, Distribution substation, bus schemes, substation location, rating of substation, calculation of voltage drops with primary feeders and secondary feeders, uniformly distributed load and Non uniformly distributed load.

UNIT IV POWER QUALITY AND DISTRIBUTION SYSTEM PERFORMANCE ANALYSIS 9

Power quality problems in distribution systems, Power quality study as per IEEE and IEC standards, Distribution Feeder Analysis – the ladder Iterative technique, Power loss calculations and control measures. Distribution system voltage regulation: voltage control, Application of capacitors in Distribution system. Case study on TNEB distribution system

UNIT V DISTRIBUTION AUTOMATION 9

Definitions, Distribution automation planning, communication, Wireless and wired Communications- DA Communication Protocols, Architectures and user interface, sensors, Supervisory Control and Data Acquisition Systems (SCADA), Case Studies

TOTAL: 45 PERIODS

OUTCOME:

- This course will equip students to have basic knowledge in distribution system management and automation and will enhance their capability of planning and designing of distribution system.

REFERENCES:

1. James Northcote – Green, Robert Wilson, "Control and Automation of Electrical Power Distribution Systems", CRC Press, New York, 2007.
2. Turan Gonen: .Electric Power Distribution System Engineering. McGraw Hill Company. 1986
3. M.V Deshpande: .Electrical Power System Design. Tata-McGraw Hill, 1966
4. IEEE Press: IEEE Recommended practice for Electric Power Distribution for Industrial Plants, published by IEEE, Inc., 1993
5. Pansini, Electrical Distribution Engineering, The Fairmont Press, Inc., 2007
6. Pabla H S.: .Electrical Power Distribution Systems.. Tata McGraw Hill. 2004
7. IEEE Standerd 739. Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities. 1984
8. G H Heydt .Electric Power Quality. McGram Hill, 2007 Wilson K. Kazibwe and Musoke H Semdaula .Electric Power Quality Control Techniques.. Van Nostarand Reinhold New York, 2006

PW7152 RENEWABLE ENERGY TECHNOLOGY L T P C
3 0 0 3

COURSE OBJECTIVE:

- To provide knowledge about various renewable energy technologies
- To provide knowledge about various possible hybrid energy systems
- To gain knowledge about application of various renewable energy technologies

UNIT I INTRODUCTION 9

Primary energy sources, renewable vs. non-renewable primary energy sources, renewable energy resources in India, Current usage of renewable energy sources in India, future potential of renewable energy in power production and development of renewable energy technologies.

UNIT II SOLAR ENERGY 9

Solar Radiation and its measurements, Solar Thermal Energy Conversion from Plate Solar Collectors, Concentrating Collectors and its Types, Efficiency and performance of collectors, Applications of Solar Thermal Energy use of low and medium, high temperature and recent advances in industry and buildings. Direct Solar Electricity Conversion from Photovoltaic, types of solar cells and its application of battery charger, domestic lighting, street lighting, and water pumping, power generation schemes. Recent Advances in PV Applications: Building Integrated PV, Grid Connected PV Systems, Hybrid Systems and Solar Cars, Solar Energy Storage system and their economic aspects.

UNIT III WIND ENERGY 9

Wind energy principles, wind site and its resource assessment, wind assessment, Factors influencing wind, wind turbine components, wind energy conversion systems(WECS), Classification of WECS devices, wind electric generating and control systems, characteristics and applications. Hybrid systems - safety and environmental aspects, economic aspects

UNIT IV BIO-ENERGY 9

Energy from biomass, Principle of biomass conversion technologies/process and their classification, Bio gas generation, types of biogas plants, selection of site for biogas plant, classification of biogas plants, Advantage and disadvantages of biogas generation, thermal gasification of biomass, biomass gasifies, Application of biomass and biogas plants and their economics.

UNIT V OTHER TYPES OF ENERGY 9

Energy conversion from Hydrogen and Fuel cells, Geo thermal energy Resources, types of wells, methods of harnessing the energy, potential in India. OTEC, Principles utilization, setting of OTEC plants, thermodynamic cycles. Tidal and wave energy: Potential and conversion techniques, mini-hydel power plants and their economics.

TOTAL: 45 PERIODS

OUTCOME:

- This subject gives a brief knowledge about the various renewable energy technologies and their applications.

REFERENCES:

1. 1.Non-Conventional Energy Sources /G.D. Rai, Khanna Publishers
2. Renewable Energy Resources – Twidell & Wier, CRC Press(Taylor & Francis)
3. Renewable energy resources/ Tiwari and Ghosal/ Narosa.
4. Renewable Energy Technologies /Ramesh & Kumar /Narosa
5. Non-Conventional Energy Systems / K Mittal /Wheeler
6. Renewable energy sources and emerging technologies by D.P.Kothari, K.C.Singhal, P.H.I.

PW7111 POWER ENGINEERING LABORATORY L T P C 0 0 4 2

COURSE OBJECTIVE:

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

LIST OF EXPERIMENTS:

1. Power flow analysis by Newton Raphson method
2. Power flow analysis by Fast decoupled method
3. Contingency analysis: Generator shift factors and line outage distribution factors
4. Economic dispatch using lambda iteration method
5. Unit commitment: Priority - list schemes and dynamic programming
6. Short circuit analysis: symmetrical and unsymmetrical
7. Characteristics of Solar PV System
8. Characteristics of Wind Energy Conversion System
9. Characteristics of Fuel Cell Based Energy Source
10. Power Management in hybrid power system

TOTAL: 60 PERIODS

OUTCOME:

- Ability to understand and analyze the power system operation and control.

PS7254 RESTRUCTURED POWER SYSTEM

L T P C
3 0 0 3

COURSE OBJECTIVES

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

UNIT I INTRODUCTION TO RESTRUCTURING OF POWER INDUSTRY 9

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

UNIT II TRANSMISSION CONGESTION MANAGEMENT 9

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

UNIT III LOCATIONAL MARGINAL PRICES AND FINANCIAL TRANSMISSION RIGHTS 9

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

UNIT IV ANCILLARY SERVICE MANAGEMENT AND PRICING OF TRANSMISSION NETWORK 9

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

UNIT V REFORMS IN INDIAN POWER SECTOR 9

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

TOTAL : 45 PERIODS

OUTCOMES

- Learners will have knowledge on restructuring of power industry
- Learners will understand basics of congestion management

- Learners will attain knowledge about locational margin prices and financial transmission rights
- Learners will understand the significance ancillary services and pricing of transmission network
- Learners will have knowledge on the various power sectors in India

TEXT BOOKS

1. Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker, "Restructured electrical power systems: operation, trading and volatility" Pub., 2001
2. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen," Operation of restructured power systems", Kluwer Academic Pub., 2001.

REFERENCES

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

PS7255 SMART GRIDS L T P C
3 0 0 3

COURSE OBJECTIVES

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

UNIT I INTRODUCTION TO SMART GRID 9

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

UNIT II SMART GRID TECHNOLOGIES (Transmission) 9

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

UNIT III SMART GRID TECHNOLOGIES (Distribution) 9

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

UNIT IV SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9

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

UNIT V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

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

TOTAL : 45 PERIODS

OUTCOMES

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

TEXT BOOKS

1. Stuart Borlase "Smart Grid :Infrastructure, Technology and Solutions",CRC Press 2012.
2. Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley.

REFERENCES*:*

1. Vehbi C. Güngör, DilanSahin, TaskinKocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, Smart Grid Technologies: Communication Technologies and Standards IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.
2. Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang "Smart Grid – The New and Improved Power Grid: A Survey" , IEEE Transaction on Smart Grids,

PW7201 GRID INTEGRATION OF RENEWABLE ENERGY SOURCES **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To study about the integration of various renewable energy sources into the grid
- To analyze the grid integration issues of renewable generation and dynamic performance of the network

UNIT I GRID INTEGRATION 9

Introduction to renewable energy grid integration - Concept of mini/micro grids and Smart grids - Different types of grid interfaces - Issues related to grid integration of small and large scale of synchronous generator based - induction generator based and converter based sources together - Network voltage management (discusses the issue of voltage levels) - Power qualitymanagement (voltage dips, harmonics, flickers and reactive power control) - Frequency management - Influence of WECS on system transient response - Interconnection standards and grid code requirements for integration.

UNIT II NETWORK INTEGRATION OF WIND POWER 9

Introduction - Wind farm starting - Network voltage management - Thermal/active power management - Network power quality management - Transient system performance - Fault level issues – Protection.

UNIT III INFLUENCE OF WIND FARMS ON NETWORK DYNAMIC PERFORMANCE 9

Dynamic Stability and its Assessment - Dynamic Characteristics of Synchronous Generation - A Synchronizing Power and Damping Power Model of a Synchronous Generator - Influence of Automatic Voltage Regulator on Damping - Influence on Damping of Generator Operating Conditions - Influence of Turbine Governor on Generator Operation - Transient Stability - Voltage Stability - Influence of Generation Type on Network Dynamic Stability - Dynamic Interaction of Wind Farms with the Network - Influence of Wind Generation on Network Transient Performance.

UNIT IV POWER SYSTEMS STABILIZERS AND NETWORK DAMPING CAPABILITY OF WIND FARMS 9

A Power System Stabilizer for a Synchronous Generator - A Power System Stabilizer for a DFIG - A Power System Stabilizer for an FRC Wind Farm.

UNIT V STAND ALONE AND GRID CONNECTED PV SYSTEM 9

Solar modules – storage systems – power conditioning and regulation - protection – standalone PV systems design – sizing - PV systems in buildings – design issues for central power stations – safety – Economic aspect – Efficiency and performance - International PV programs

TOTAL: 45 PERIODS

OUTCOME:

- This course provides a brief knowledge about integration of various renewable energy sources into the grid and its issues.

TEXT BOOKS:

1. Eduardo Lorenzo G. Araujo, Solar electricity engineering of photovoltaic systems,Progensa,1994.
2. Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, Applied Photovoltaics, 2007,Earthscan, UK.

REFERENCES

1. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright and Mike Hughes :" WIND ENERGY GENERATION Modelling and Control" A John Wiley and Sons, Ltd., Publication (2009)
2. Brendan Fox, Damian Flynn and Leslie Bryans: "Wind Power Integration Connection and system operational aspects" Published by The Institution of Engineering and Technology, London, United Kingdom (2007).
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.

PW7251	SCADA SYSTEM AND APPLICATIONS MANAGEMENT	L T P C
		3 0 0 3

COURSE OBJECTIVE:

- To understand about the SCADA system components and SCADA communication protocols
- To provide knowledge about SCADA applicatios in power system

UNIT I INTRODUCTION TO SCADA **9**

Evolution of SCADA, SCADA definitions, SCADA Functional requirements and Components, SCADA Hierarchical concept, SCADA architecture, General features, SCADA Applications, Benefits

UNIT II SCADA SYSTEM COMPONENTS **9**

Remote Terminal Unit (RTU), Interface units, Human- Machine Interface Units (HMI), Display Monitors/Data Logger Systems, Intelligent Electronic Devices (IED), Communication Network, SCADA Server, SCADA Control systems and Control panels

UNIT III SCADA COMMUNICATION **9**

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

UNIT IV SCADA MONITORING AND CONTROL **9**

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

UNIT V SCADA APPLICATIONS IN POWER SYSTEM **9**

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

CASE STUDIES:

SCADA Design for 66/11KV and 132/66/11KV or 132/66 KV any utility Substation and IEC 61850 based SCADA Implementation issues in utility Substations,

TOTAL: 45 PERIODS

OUTCOME:

- This course gives knowledge about various system components and communication protocols of SCADA system and its applications.

REFERENCES:

1. Stuart A. Boyer: SCADA-Supervisory Control and Data Acquisition, Instrument Society of America Publications,USA,2004
2. Gordon Clarke, Deon Reynders: Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems, Newnes Publications, Oxford, UK,2004
3. William T. Shaw, Cybersecurity for SCADA systems, PennWell Books, 2006
4. David Bailey, Edwin Wright, Practical SCADA for industry, Newnes, 2003
5. Michael Wiebe, A guide to utility automation: AMR, SCADA, and IT systems for electric Power, PennWell 1999
6. Dieter K. Hammer, Lonnie R. Welch, Dieter K. Hammer, "Engineering of Distributed Control Systems", Nova Science Publishers, USA, 1st Edition, 2001

PW7211	**ENERGY LABORATORY**	**L T P C**
		0 0 4 2

COURSE OBJECTIVE:

- To provide hands on experience on various renewable energy conversion equipments
- To provide hands on experience to understand about various energy conservation technolgies

RENEWABLE ENERGY **18**

1. Performance testing of Solar Water Collector
2. Characteristics of Solar photovoltaic devices

3. Testing of Gasifier
4. Testing of biogas plant
5. Properties of Fuels
6. Solar Radiation measurement

ENERGY CONSERVATION **18**

1. Boiler efficiency testing
2. Motor and Pump efficiency testing
3. Energy consumption measurement of lighting systems
4. VFD Drives
5. Heat Exchangers
6. Refrigeration and Air conditioning systems

ADVANCED ENERGY SYSTEMS **9**

1. Fuel Cell
2. Earth Energy
3. Thermal Storage Systems

EQUIPMENTS REQUIRED

1. Solar water heater – 100 LPD
2. SPV Educational Kit
3. 20 kWe gasifier
4. Biogas plant (fixed dome or floating drum)
5. Bomb calorimeter
6. Junker's gas calorimeter
7. Hydrometer
8. Flash and fire point apparatus
9. Proximate analyser (Muffle furnace and micro weigh balance)
10. Solar Radiation Meters
11. Non-IBR boiler
12. 5 HP motor efficiency test rig
13. Pump efficiency test rig
14. VFD coupled to a varying load device
15. Heat Exchangers (plate, pipe-in-pipe, shell and tube)
16. Vapour Compression Refrigeration Test Rig
17. Fuel cell – Educational Kit
18. PCM based energy storage system

TOTAL: 60 PERIODS

OUTCOMES :

- Provides hand-on experience in analyzing the performance of various energy conversion equipments.

PW7351 **ENERGY MANAGEMENT AND AUDITING** **L T P C**
3 0 0 3

COURSE OBJECTIVES

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

UNIT I INTRODUCTION 9

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

UNIT II ENERGY COST AND LOAD MANAGEMENT 9

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

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

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

UNIT IV METERING FOR ENERGY MANAGEMENT 9

Relationships between parameters-Units of measure-Typical cost factors- Utility meters - Timing of meter disc for kilowatt measurement - Demand meters - Paralleling of current transformers - Instrument transformer burdens-Multitasking solid-state meters - Metering location vs. requirements- Metering techniques and practical examples

UNIT V LIGHTING SYSTEMS & COGENERATION 9

Concept of lighting systems - The task and the working space -Light sources - 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.

TOTAL: 45 PERIODS

OUTCOME

- Students will develop the ability to learn about the need for energy management and auditing process
- Learners will learn about basic concepts of economic analysis and load management.
- Students will understand the energy management on various electrical equipments.
- Students will have knowledge on the concepts of metering and factors influencing cost function
- Students will be able to learn about the concept of lighting systems, light sources and various forms of cogeneration

TEXT BOOKS

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, Guide to Energy Management, Fifth Edition, The Fairmont Press, Inc., 2006
2. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists,. Logman Scientific & Technical, ISBN-0-582-03184, 1990.

REFERENCES

1. Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.
2. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 196.
3. Amit K. Tyagi, Handbook on Energy Audits and Management, TERI, 2003.

PW7072 ELECTRIC VEHICLES AND POWER MANAGEMENT **L T P C**

3 0 0 3

COUSE OBJECTIVE:

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

UNIT I ELECTRIC VEHICLES AND VEHICLE MECHANICS **9**

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

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

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

UNIT III CONTROL OF DC AND AC DRIVES **9**

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

UNIT IV BATTERY ENERGY STORAGE SYSTEM **9**

Battery Basics, Different types, Battery Parameters, Battery modeling, Traction Batteries

UNIT V ALTERNATIVE ENERGY STORAGE SYSTEMS **9**

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

TOTAL :45 PERIODS

OUTCOME:

- This course equips the student to understand the operation of Electric vehicles and various energy storage technologies for electrical vehicles.

REFERENCES

1. Iqbal Hussain, CRC Press, Taylor & Francis Group, Second Edition (2011).
2. Ali Emadi, Mehrdad Ehsani, John M.Miller Vehicular Electric Power Systems, Special Indian Edition, Marcel dekker, Inc 2010

PW7071 CLIMATE CHANGE AND ENERGY ENVIRONMENT L T P C
3 0 0 3

COURSE OBJECTIVE:

- To provide knowledge about climate change and its environmental impact
- To provide knowledge about technology and policy options for GHG emission
- To provide knowledge about international climate change conventions, protocols and perspectives

UNIT I CLIMATE CHANGE 9

Energy use and Global Warming, Climate Change Concerns, Climate Change in India, the Greenhouse Effect, Earth's Radiation balance, Greenhouse Gases (GHG) types and Sources, Climate Change Impacts

UNIT II TECHNOLOGY AND POLICY OPTIONS FOR GHG EMISSION MITIGATION 9

Renewable Energy, Energy Efficient Technologies by Sector and End-Use, Cleaner Production, Barriers to GHG Mitigation Technologies, Carbon tax and Tradable Emission Permits, Other Policy Options

UNIT III INTERNATIONAL CLIMATE CHANGE CONVENTIONS, PROTOCOLS AND PERSPECTIVES 9

Climate Change in India and mitigation measures on Indian perspectives, United Nations Framework Convention on Climate Change (UNFCCC), Clean Development Mechanism (CDM) as per the Kyoto Protocol and Flexible Mechanisms, comparison on India vs developed countries perspectives on GHG mitigations

UNIT IV ENVIRONMENTAL PROBLEMS RELATED TO ENERGY USE 9

Energy use and its air pollution, acid rain, Technological and policy options for control of SO2 and NOx emissions, the problem of Atmospheric Brown Cloud (ABC) and possible mitigation options

UNIT V URBAN ENERGY USE AND THE ENVIRONMENT 9

Efficient/cleaner transport options of electric vehicles and their effects on energy use, environment and GHG emissions, other options to improve energy use and environment in urban areas

TOTAL: 45 PERIODS

OUTCOME:

- This course provides brief knowledge about climate change and its environmental impact and provides knowledge about technologies and policy options to overcome the impact of climate change.

REFERENCES

1. R. T. Watson, M. C. Zinyowera, and R. H. Moss (eds.): Technologies, Policies, and Measures for Mitigating Climate Change, IPCC Technical Paper No. 1, Intergovernmental Panel on Climate Change, 1996.
2. L. D. D. Harvey: Climate and Global Environmental Change, Prentice Hall, 2000.
3. W. D. Nordhaus: Managing the Global Commons: The Economics of Climate Change, The MIT Press, Cambridge, USA, 1994.
4. C.S.Pearson: Economics and the Global Environment, Cambridge University Press, Cambridge, UK, 2000.
5. W.R. Cline: The Economics of Global Warming, Institute for International Economics, Washington, D.C., 1992.
6. United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1998.
7. Intergovernmental Panel on Climate Change (IPCC), Special Report on Emission Scenarios, Cambridge University Press, Cambridge, 2000.
8. M. Grubb, C. Vrolijk and D. Brack: The Kyoto Protocol, Earthscan, London, 1999
9. UNEP and C4, The Asian Brown Cloud: Climate and Other Environmental Impacts, UNEP, Nairobi, 2002

PW7074 ENERGY ECONOMICS, FINANCING, REGULATION AND ENERGY MODELING

L T P C
3 0 0 3

COURSE OBJECTIVE:

- To provide knowledge about importance of energy economics
- To give an overview about the energy policies, energy planning and policy making in india
- To model and analyze the energy demand

UNIT I INTRODUCTION 9

Law of demand, Elasticity of demand, Theory of firm: Production function, output maximization, cost minimization and profit maximization principles. Theory of market, National income and other macroeconomic parameters; Integrated framework for energy pricing, basic pricing principles, short run versus long run marginal cost pricing, peak load and seasonal pricing. Energy Prices and Markets, Pricing of Exhaustible Resources, Economic regulation of energy markets.

UNIT II BASIC CONCEPTS OF ENERGY ECONOMICS 9

Calculation of unit cost of power generation from different sources with examples Ground rules for investment in Energy sector, Payback period, NPV, IRR and Benefit-cost analysis with example Investment in Energy Resources: Economics of discount rate, concept of net present value, incremental costs and benefits, cash flow analysis, private and social costs Discussion on investing in energy projects, financial and economic analysis of energy technologies, short run and long run implications of conventional energy systems,

UNIT III SOCIO-ECONOMIC EVALUATION OF ENERGY CONSERVATION PROGRAMMES 9

Net Social Benefit incorporating- Free riding concept and Rebound affects Energy-GDP elasticity,

UNIT IV OVERVIEW OF ENERGY POLICIES, ENERGY PLANNING AND POLICY MAKING IN INDIA 9

National energy policy in the last plan periods, Energy use and Energy supply, Overview of renewable energy policy and the Five Year Plan programmes, Basic concept of Input-Output analysis, Concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy Organizational structure, key developments and changes in India's energy policies and planning in the context of energy efficiency and environmental concerns, regulatory frameworks and reforms across various energy sectors, success stories, failures and lessons learnt.

UNIT V MODELS AND ANALYSIS OF ENERGY DEMAND 9

Analysis of Environmental Pollution through decomposition of different sectors using I-O model, Interdependence of energy, economy and environment, Modeling concepts and application of SIMA model and I-O model for energy policy analysis, Simulation and forecasting of future energy demand consistent with macroeconomic parameters in India. Basic concept of Econometrics (OLS) and statistical analysis (Multiple Regression), Econometrics techniques used for energy analysis and forecasting with case studies from India Economy-Energy-Environment Modeling Quantitative modeling frameworks, review of various energy sector models, concepts in modeling energy resources, technological developments; Energy modeling in the context of climate change

TOTAL: 45 PERIODS

OUTCOME:

- This course gives an overview about the energy economics, energy planning, energy policies and energy demand.

REFERENCES

1. EA Diulio, Macroeconomic Theory, Schaum's Outline Series, 2nd Ed, McGraw-Hill Publishing Company (1990)
2. R Loulou, P R Shukla and A Kanudia, Energy and Environment Policies for a sustainable Future, Allied Publishers Ltd, New Delhi, 1997
3. J Parikh, Energy Models for 2000 and Beyond, Tata McGraw-Hill Publishing Company Ltd, New Delhi,1997
4. "Energy," Science, Vol. 285, No. 5427 (30 July 1999), pp. 677-711.
5. Adelman, M.A. (2002): "World Oil Production and Prices 1947-2000," The Quarterly Review of Economics and Finance, 42: 169-191.
6. Barretto, L., A. Makihira and K. Riahi (2003): "The hydrogen economy in the 21st century:
7. a sustainable development scenario," International Journal of Hydrogen Energy, 28: 267-284.
8. Ben Esty and Michael Kane. 2001. "Calpine Corp: The Evolution from Project to Corporate Finance," Harvard Business School Case: 201098.
9. Bentley, R.W. (2002): "Global oil & gas depletion: an overview," Energy Policy, 30: 189-205
10. Bohi, D. P. (1981): Analyzing Demand Behavior: A Study of Energy Elasticities, JohnsHopkins University Press.

PW7002 ENERGY SYSTEMS MODELING AND ANALYSIS **L T P C**
3 0 0 3

COURSE OBJECTIVES:

- To learn to apply mass and energy balances for the systems and enable to perform enthalpy
- Learn to calculate to size performance and cost of energy equipment turns modeling and simulation techniques.
- Learn to optimize the energy system for its maximum or minimum performance output.

UNIT I INTRODUCTION 9

Primary energy analysis - dead states and energy components - energy balance for closed and control volume systems - applications of energy analysis for selected energy system design - modeling overview - levels and steps in model development - examples of models – curve fitting and regression analysis.

UNIT II MODELLING AND SYSTEMS SIMULATION 9

Modeling of energy systems – heat exchanger - solar collectors – distillation -rectification turbo machinery components - refrigeration systems - information flow diagram - solution of set of non-linear algebraic equations - successive substitution - Newton Raphson method- examples of energy systems simulation.

UNIT III OPTIMISATION TECHNIQUES 9

Objectives - constraints, problem formulation - unconstrained problems - necessary and sufficiency conditions.Constrained optimization - lagrange multipliers, constrained variations, Linear Programming - Simplex tableau, pivoting, sensitivity analysis.

UNIT IV ENERGY- ECONOMY MODELS 9

Multiplier Analysis - Energy and Environmental Input / Output Analysis - Energy Aggregation – Econometric Energy Demand Modeling - Overview of Econometric Methods - Dynamic programming - Search Techniques - Univariate / Multivariate.

UNIT V APPLICATIONS AND CASE STUDIES 9

Case studies of optimization in Energy systems problems- Dealing with uncertainty-probabilistic techniques – Trade-offs between capital and energy using Pinch analysis.

TOTAL : 45 PERIODS

OUTCOME:

- This course provides knowledge to the learner about modelling of energy system and to optimize the energy system for its maximum and minmum performance.

TEXT BOOKS:

1. Stoecker, W.F., Design of Thermal Systems, McGraw Hill, 1989.
2. Bejan, A, Tsatsaronis, G and Moran, M., Thermal Design and Optimization, John Wiley & Sons 1996.

REFERENCES:

1. Rao, S.S., Engineering Optimization - Theory and Applications, Wiley Eastern, 2000.
2. Meier, P., Energy Systems Analysis for Developing Countries, Springer Verlag, 1984.
3. Beveridge and Schechter, Optimization Theory and Practice, McGraw Hill, 1970.
4. Jaluria, S., Design and Optimization of Thermal Systems, McGrawHill, 1997.

PW7075 SUSTAINABLE ENERGY UTILZATION L T P C
3 0 0 3

COURSE OBJECTIVE:

- To understand the need of energy in building
- To study the heat flow calculations in building
- To understand the passive cooling/heating concept
- To provide knowledge about energy efficient building and electric energy conservation in buildings

UNIT I HEAT FLOW CALCULATION IN BUILDING 9

Unsteady heat flows through walls, roof, windows etc. Direct heat gains through windows. Convective gains/losses, air exchange rates. Gains from people, appliances etc. Air conditioning load calculations

UNIT II NEED OF ENERGY IN BUILDINGS 9

Role of building design and building services to evaluate the energy performance in buildings. Study of Climate and its influence in building design for energy requirement - Environmental science of buildings - Study of Thermal environment and visual environment - Heat gain and heal loss phenomenon of buildings - Role of building enclosures, openings and materials in thermal environment -Energy efficient light design of buildings - Design for visual environment. Energy rating of buildings - Description of different components of HVAC Passive and low energy concepts and applications.

UNIT III PASSIVE COOLING / HEATING CONCEPTS 9

Building form and orientation, internal and external shading devices, ventilation, passive concepts for composite climates, evaporative and nocturnal cooling, earth–air tunnel, sky-therm system, and solar chimney-based hybrid system.
Introduction and use of different building simulation software such as TRNSYS, ECOTECT etc.- Case studies of non-air conditioned buildings- Case studies of air conditioned buildings

UNIT IV ENERGY EFFICIENT BUILDINGS 9

Introduction - Definition and concepts, Energy and Water as a resource,- Criticality of resources and needs of modern living - Envelop heat loss and heat gain and its evaluation, Thermal Comport improvement methods, Optimum performance, other building comports, IAQ requirements.

UNIT V ELECTRICAL ENERGY CONVERSION 9

Opportunities and Techniques for energy conservation in Buildings - Adoption to sustainable resources, process and Technologies. Green Buildings, Intelligent Buildings, Rating of Buildings, Efficient Use of Buildings, Solar Passive Architecture, Eco-housing concepts and National and International norms.

TOTAL: 45 PERIODS

OUTCOME:

- This course equips students to know about need of energy in building and various conservation techniques to use energy in sustainable manner.

REFERENCES

1. Koenigsberger, et.al Manual of Tropical housing and Building Longman Group Ltd London (now published by Orient Longman Ltd, Madras, India),1974
2. Oliver and Daniel, D Chiras Natural Resource Conservation Management for a sustainable future, Prentice Hall International Ltd, London, 1992
3. USAID International resource book, Energy Conservation Building design Tip Sheet - Building Lighting Design,
4. MS Sodha, NK Bansal, PK Bansal, A Kumar and MAS Malik, Solar Passive Building, Science and Design, Pergamon Press, 1986
5. JR Williams, Passive Solar Heating, Ann Arbar Science, 1983
6. RWJones, JD Balcomb, CE Kosiewiez, GS Lazarus, RD McFarland and WOWray, Passive Solar Design Handbook, Vol 3, Report of US Department of Energy (DOE/CS-0127/3), 1982
7. J Krieder and A Rabi, Heating and Cooling of Buildings: Design for Efficiency, McGraw-Hill, 1994
8. RD Brown, TJ Gillespie, Microclimatic Landscape Design, John Wiley and Sons, New York, 1990
9. TA Markus, EN Morris, Building, Climate and Energy, Spottwoode Ballantype Ltd, London, 1980

PE7152 ANALYSIS OF ELECTRICAL MACHINES LT P C
3 0 0 3

OBJECTIVES:

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

UNITI PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9

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

UNIT II DC MACHINES **9**

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

UNIT III REFERENCE FRAME THEORY **9**

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

UNIT IV INDUCTION MACHINES **9**

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

UNIT V SYNCHRONOUS MACHINES **9**

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

TOTAL : 45 PERIODS

OUTCOMES:

- Ability to acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering.
- Ability to model and analyze power electronic systems and equipment using computational software.
- Ability to formulate, design, simulate power supplies for generic load and for machine loads.
- Ability to optimally design magnetics required in power supplies and drive systems.

TEXT BOOKS

1. Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition, 2010.

REFERENCES

1. P S Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers, 2008.
2. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, " Electric Machinery", Tata McGraw Hill, 5th Edition, 1992.

CO7152 SOFT COMPUTING TECHNIQUES LT P C

3 0 0 3

COURSE OBJECTIVES

- To review the fundamentals of ANN and fuzzy set theory.
- To make the students understand the use of ANN for modeling and control of non-linear system and to get familiarized with the ANN tool box.
- To impart knowledge of using Fuzzy logic for modeling and control of non-linear systems and get familiarized with the FLC tool box.
- To make the students to understand the use of optimization techniques.
- To familiarize the students on various hybrid control schemes, P.S.O and get familiarized with the ANFIS tool box.

UNIT I OVERVIEW OF ARTIFICIAL NEURAL NETWORK (ANN) & FUZZY LOGIC 9

Review of fundamentals - Biological neuron, Artificial neuron, Activation function, Single Layer Perceptron – Limitations – Multi Layer Perceptron – Back propagation algorithm (BPA); Fuzzy set theory – Fuzzy sets – Operation on Fuzzy sets - Scalar cardinality, fuzzy cardinality, union and intersection, complement (yager and sugeno), equilibrium points, aggregation, projection, composition, fuzzy relation – Fuzzy membership functions.

UNIT II NEURAL NETWORKS FOR MODELLING AND CONTRO 9

Generation of training data - optimal architecture – Model validation- Control of non linear system using ANN- Direct and Indirect neuro control schemes- Adaptive neuro controller – Case study - Familiarization of Neural Network Control Tool Box.

UNIT III FUZZY LOGIC FOR MODELLING AND CONTROL 9

Modeling of non linear systems using fuzzy models(Mamdani and Sugeno) –TSK model - Fuzzy Logic controller – Fuzzification – Knowledge base – Decision making logic – Defuzzification-Adaptive fuzzy systems- Case study - Familiarization of Fuzzy Logic Tool Box.

UNIT IV GENETIC ALGORITHM 9

Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other search techniques like Tabu search, Ant-colony search and Particle Swarm Optimization.

UNIT V HYBRID CONTROL SCHEMES 9

Fuzzification and rule base using ANN–Neuro fuzzy systems-ANFIS –Optimization of membership function and rule base using Genetic Algorithm and Particle Swarm Optimization - Case study– Familiarization of ANFIS Tool Box.

TOTAL : 45 PERIODS

COURSE OUTCOME

Students,

- Will be able to know the basic ANN architectures, algorithms and their limitations.
- Also will be able to know the different operations on the fuzzy sets.

- Will be capable of developing ANN based models and control schemes for non-linear system.
- Will get expertise in the use of different ANN structures and online training algorithm.
- Will be knowledgeable to use Fuzzy logic for modeling and control of non-linear systems.
- Will be competent to use hybrid control schemes and P.S.O.

REFERENCES

1. Laurene V.Fausett, “Fundamentals of Neural Networks, Architecture, Algorithms, and Applications”, Pearson Education, 2008.
2. Timothy J.Ross, “Fuzzy Logic with Engineering Applications”, Wiley, Third Edition, 2010.
3. David E.Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Pearson Education, 2009.
4. W.T.Miller, R.S.Sutton and P.J.Webrose, “Neural Networks for Control”, MIT Press, 1996.
5. George J.Klir and Bo Yuan, “Fuzzy Sets and Fuzzy Logic: Theory and Applications”, Prentice Hall, First Edition, 1995.
6. N.P Padhy, S.P. Simon “Soft Computing With MATLAB Programming”,OXFORD print Feburary 2015.

PS7071 DISTRIBUTED GENERATION AND MICRO GRID L T P C
3 0 0 3

OBJECTIVES

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

UNIT I INTRODUCTION 9

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

UNIT II DISTRIBUTED GENERATIONS (DG) 9

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

UNIT III IMPACT OF GRID INTEGRATION 9

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

UNIT IV BASICS OF A MICROGRID 9

Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids,

UNIT V CONTROL AND OPERATION OF MICROGRID 9

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

TOTAL : 45 PERIODS

OUTCOMES

- Students will attain knowledge on the various schemes of conventional and non-conventional power generation.
- Students will have knowledge on the topologies and energy sources of distributed generation.
- Students will learn about the requirements for grid interconnection and its impact with NCE sources
- Students will understand the fundamental concept of Microgrid.

REFERENCES

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

PW7001 ENERGY EFFICIENT BUILDINGS L T P C
3 0 0 3

COURSE OBJECTIVE:

- To understand about the principle of energy conscious building design
- To understand about the concept of passive solar heating and efficient technologies in electrical system
- To provide knowledge about the energy conservation techniques in buildings

UNIT I CLIMATE AND SHELTER 9

Historic buildings – Modern architecture – Examples from different climate zones – Thermal comfort – Solar geometry and shading – Heating and cooling loads – Energy estimates and site planning – Integrative Modeling methods and building simulation.

UNIT II PRINCIPLES OF ENERGY CONSCIOUS BUILDING DESIGN 9

Energy conservation in buildings – Day lighting – Water heating and photovoltaic systems – Advances in thermal insulation – Heat gain/loss through building components – Solar architecture.

UNIT III PASSIVE SOLAR HEATING 9

Direct gain – thermal storage wall – Sunspace – Convective air loop – Passive cooling – Ventilation - Radiation – Evaporation and Dehumidification – Mass effect – Design guidelines.

UNIT IV ENERGY CONSERVATION IN BUILDING 9

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

UNIT V EFFICIENT TECHNOLOGIES IN ELECTRICAL SYSTEMS 9

Maximum demand controllers, automatic power factor controllers, energy efficient motors, and soft starters

TOTAL : 45 PERIODS

OUTCOMES:

This course will give knowledge about the energy conscious building design and energy conservative techniques in building design.

REFERENCES :

1. J. A. Clarke, Energy Simulation in Building Design (2e) Butterworth 2001.
2. J. K. Nayak and J. A. Prajapati Hadbook on Energy Consious Buildings, Solar Energy control MNES,2006.
3. Energy conservation Building Codes 2006; Bereau of Energy Efficiency.
4. J. R. Williams, Passive Solar Heating, Ann Arbar Science, 1983.
5. R. W. Jones, J. D. Balcomb, C. E. Kosiewiez, G. S. Lazarus, R. D. McFarland and W. O. Wray,Passive Solar Design Handbook, Vol. 3, Report of U. S. Department of Energy (DOE/CS-0127/3),1982.
6. M. S. Sodha, N. K,. Bansal, P. K. Bansal, A. Kumar and M. A. S. Malik. Solar Passive Building,Science and Design, Pergamon Press, 1986.
7. J. L. Threlkeld, Thermal Environmental Engineering, Prentice Hall, 1970

PW7003 GOVERNANCE AND MANAGEMENT OF NATURAL RESOURCES **L T P C 3 0 0 3**

COURSE OBJECTIVE:

- To understand the importance of natural resource governance and its management
- To provide knowledge about the international and national efforts for governing the natural resource
- To provide knowledge about the various natural energy sources and its economics

UNIT I INTRODUCTION 9

Legal and political environments in resource management - Global and local governance, challenges of good governance - Ostrom design principles and basic frameworks - organizational structure and stakeholders in NRM and livelihood - Natural Resource Governance in rapidly changing world

UNIT II INTERNATIONAL AND NATIONAL EFFORTS 9

CITES and other international treaties and conventions, roles of international organizations and NGOS with special reference to UN and specialized agencies, institutional regulatory bodies and authorities: direct intervention by the state, green business and green ethics, stakeholder analysis, understanding and managing governance issue - governance tactics and tools - CSR (Corporate Social Responsibility) as a tool for sustainable NRM based business - Case studies about corporate social responsibility - Corporate social responsibility (CSR), NRM based CSR action - E-governance, Climate change and corporate responses

UNIT III IMPORTANCE OF THE ENVIRONMENT AND NATURAL RESOURCES 9

A brief account of natural resources and their utilization and conservation in India - Sustaining the Environment -Resource Conservation -Population Demands. International and National Policy instruments - Principles of integrated Natural Resource Management.

UNIT IV ENERGY RESOURCES 9

Renewable and Non renewable sources of energy and their management- Fossil fuel management - coal, oil and petroleum, oil shale, natural gas. Wind Energy- prospects and limitations. Solar energy – applications for rural and urban energy subsidy. Wave, Tidal, Geothermal energy - –biodiesel production and its importance Bio-energy – wood, fuels from crops-Ethanol-Production.

UNIT V ECONOMICS OF NATURAL RESOURCES 9

Systems approach in natural capital management - Fundamentals of renewable and non-renewable resource economics. Valuation of natural resources - Environmental accounting, Ecological footprints, Bioprospecting for genetic resources - Principles of handling risk, uncertainty, and sensitivity. Decision making under uncertainty and option value. Understanding the Stakeholders approach- Subsistence groups- Governments-Academic institutions- Conflicts and competing uses.

TOTAL: 45 PERIODS

OUTCOME:

- This course provides knowledge about the importance of managing the natural resources and economics of natural resources.

REFERENCES

1. Natural Resource Management: Need for 21st Century/Sunit Gupta and Mukta Gupta. 1998, Community-Based Natural Resource Management: Issues and Cases from South Asia by Ajit Menon, Praveen Singh, Esha Shah, Sharachchandra Lélé, Suhas Paranjape and K.J.Joy, SAGE, 2007
2. Natural Resources Management Practices: A Primer. by Peter F. F Folliott, Luis A. Bojorquez- Topia, Mariano Hernandez-Narvaez, 2001, Iowa State University Press Remote Sensing And Gis For Natural Resource Management, Bir Abhimanyu Kumar, Academic Excellence Publishers, 2007.
3. Bhattacharya P., Kandya A.K. and Krishna Kumar 2008. Joint Forest management in india,aavishkar publisher,Jaipur.
4. Daily, Gretchen, editor, et al. 1997. Nature's services: societal dependence on natural ecosystems. Island press.
5. Kareiva, peter, et al. 2011. Natural capital: theory and practice of mapping ecosystemservices. Oxford.
6. Kareiva, peter, and Michelle marview. 2010. Conservation science: balancing the needs of people and nature. roberts and company
7. Knight, Richard l., editor, et al. 1995. A new century for natural resources management. Island Press.
8. Heal, Geoffrey. 2000. Nature and the marketplace: capturing the value of ecosystem services. Island press.

PW7076 URBAN AND RURAL ENERGY MANAGEMENT L T P C

3 0 0 3

COURSE OBJECTIVE:

- To give introduction about indian energy scenario
- To provide knowledge about urban and rural environment and its energy demand
- To understand the concept of green building and electric vehicle charging station

UNIT I INDIAN ENERGY SCENARIO 9

Commercial and non-commercial forms of energy, energy consumption pattern and Its variation as a function of time, energy resources available in India, urban and rural energy consumption, nuclear energy - promise and future, energy as a factor limiting growth, need for use of new and renewable energy sources.

UNIT II URBAN ENVIRONMENT AND GREEN BUILDINGS 9

Patterns of fuel consumption: agricultural, domestic, industrial and community needs, Projection of energy demands, Optimization of use of various energy sources, Substitution of conventional energy sources by alternative sources and more efficient modern technologies Utility of Solar energy in buildings concepts of Solar Passive Cooling and Heating of Buildings Low Energy Cooling. Case studies of Solar Passive Cooled and Heated Buildings

UNIT III URBAN ELECTRIC VEHICLE CHARGING STATIONS 9

Electric vehicle charging stations- Integration of PHEV into Energy Networks – Impact on Distribution Systems – DC Fast Charging – Co-ordinated charging- V2G technology

UNIT IV THE RURAL ENERGY SITUATION 9

effects of Bio fuel use in rural India. Pollution and Health Ecological damage, Energy efficiency, the transition to modern energy, Rural Electrification policy.

UNIT V OPTION FOR RURAL ELECTRIFICATION 9

Cost Effectiveness and choice of options, Costs of Grid Supplies, Reducing initial investment costs by using appropriate design standards, Micro-grids supplied by diesel generators, Electricity Supplies from Renewable Energy Sources.

TOTAL: 45 PERIODS

OUTCOME:

- Students will get idea about utilization of energy in rural and urban areas

REFERENCES

1. Tools & methods for Integrated Resource Planning - Joel N.Swisher, Gilberto de Martino Jannzzi Robert Y. Red Linger,Publisher UNEP Collaborating Centre on Energy & Environment, RISO National Laboratory, Denmark, Nov. - 1997
2. Integrated Resource Planning & Demand Side Management through Regulation – 2002 sponsored by US AID. Integrated Energy Policy of India - 2006

PE7073 **POWER QUALITY** **L T P C**
3 0 0 3

OBJECTIVES :

- To understand the various power quality issues.
- To understand the concept of power and power factor in single phase and three phase systems supplying non linear loads
- To understand the conventional compensation techniques used for power factor correction and load voltage regulation.
- To understand the active compensation techniques used for power factor correction.
- To understand the active compensation techniques used for load voltage regulation.

UNIT I INTRODUCTION 9

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

UNIT II ANALYSIS OF SINGLE PHASE AND THREE PHASE SYSTEM 9

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

UNIT III CONVENTIONAL LOAD COMPENSATION METHODS 9

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

UNIT IV LOAD COMPENSATION USING DSTATCOM 9

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

UNIT V SERIES COMPENSATION OF POWER DISTRIBUTION SYSTEM 9

Rectifier supported DVR – Dc Capacitor supported DVR – DVR Structure–voltage Restoration – Series Active Filter – Unified power quality conditioner.

TOTAL : 45 PERIODS

OUTCOME:

- Ability to formulate, design, simulate power supplies for generic load and for machine loads.
- Ability to conduct harmonic analysis and load tests on power supplies and drive systems.
- Ability to understand and design load compensation methods useful for mitigating power quality problems.

TEXT BOOKS

1. ArindamGhosh “Power Quality Enhancement Using Custom Power Devices”, Kluwer Academic Publishers, 2002
2. G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition)
3. Power Quality - R.C. Duggan
4. Power system harmonics –A.J. Arrillga
5. Power Electronic Converter Harmonics –Derek A. Paice

PE7252 MODELLING AND DESIGN OF SMPS **L T P C**
3 0 0 3

OBJECTIVE

- To provide conceptual knowledge in modern power electronic converters and its applications in electric power utility.

UNIT I STEADY-STATE CONVERTER ANALYSIS 9

Buck, Boost, Buck- Boost and Cuk converters: Principles of operation – Continuous conduction mode – Concepts of volt-sec balance and charge balance – Analysis and design based on steady-state relationships – Introduction to discontinuuous conduction more – Isolation topologies.

UNIT II CONVERTER DYNAMICS 9

AC equivalent circuit analysis – Sate space averaging – Circuit averaging – Averaged switch modeling – Transfer function model for buck, boost, buck-boost and cuk converters – Input filters.

UNIT III CONTROLLER DESIGN 9

Review of P, PI, and PID control concepts – gain margin and phase margin – Bode plot based analysis – Design of controller for buck, boost, buck-boost and cuk converters.

UNIT IV DESIGN OF MAGNETICS 9

Basic magnetic theory revision – Inductor design – Design of mutual inductance – Design of transformer for isolated topologies – Ferrite core table and selection of area product – wire table – selection of wire gauge.

UNIT V RESONANT CONVERTERS 9

Introduction- classification- basic concepts- Resonant switch- Load Resonant converters- ZVS, Clamped voltage topologies- Series and parallelResonant converters- Voltage control.

TOTAL: 45 PERIODS

OUTCOME:

- Ability to acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering.

- Ability to optimally design magnetics required in power supplies and drive systems.
- Ability to design and conduct experiments towards research.

TEXT BOOKS:

1.Robert W. Erickson &Dragon Maksimovic" Fundamentals of Power Electronics" Second Edition, 2001 Springer science and Business media

REFERENCES:

1. John G.Kassakian, Martin F. Schlecht, George C. Verghese, "Principles of Power Electronics" Pearson, India, New Delhi, 2010.
2. Simon Ang and Alejandra Oliva, "Power Switching Converter" Yesdee publishers, New Delhi, 2nd edition (first Indian Reprint), 2010.
3. Philip T Krein, " Elements of Power Electronics", Oxford University Press

PS7253	**FLEXIBLE AC TRANSMISSION SYSTEMS**	**L T P C**
		3 0 0 3

COURSE OBJECTIVES

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

UNIT I INTRODUCTION 9

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

UNIT II STATIC VAR COMPENSATOR (SVC) 9

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

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

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

UNIT IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9

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

UNIT V CONTROLLERS AND THEIR COORDINATION 9

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

TOTAL : 45 PERIODS

OUTCOMES

- Learners will be able to refresh on basics of power transmission networks and need for FACTS controllers
- Learners will be able to explain about static var compensator in detail
- Learners will attain knowledge about Controlled Series Compensation
- Learners will understand the significance about different voltage source converter based facts controllers
- Learners will be able to analyze on FACTS controller interaction and control coordination

TEXT BOOKS

1. Mohan Mathur, R., Rajiv. K. Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons, Inc.
2. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International(P) Ltd., Publishers, New Delhi, Reprint 2008,

REFERENCES:

1. A.T.John, "Flexible AC Transmission System", Institution of Electrical and Electronic Engineers (IEEE), 1999.
2. Narain G.Hingorani, Laszio. Gyugyl, "Understanding FACTS Concepts and Technology of Flexible AC Transmission System", Standard Publishers, Delhi 2001.
3. V.K.Sood, "HVDC and FACTS controllers- Applications of Static Converters in Power System", 2004, Kluwer Academic Publishers.

PW7073 ELECTRICITY MARKET ANALYSIS L T P C

3 0 0 3

COURSE OBJECTIVE:

- To provide brief introduction on restructuring of power system and various market models
- To provide knowledge about demand and price forecasting and price based unit commitment
- To provide knowledge about transmission congestion management and pricing
- To provide knowledge about electricity trading, generator asset valuation and risk management

UNIT I INTROUCTION OF RESTRUCTURING AND MARKET MODELS 9

Restructuring of Utilities- Different Models: PoolCo Model, Bilateral Contracts Model, Hybrid Model Independent System Operator (ISO)- The Role of ISO - Power Exchange(PX): Market Clearing Price(MCP) - Market operations: Day-ahead and Hour-Ahead Markets, Elastic and Inelastic Markets– Block forwards Market - Market Structure – Power Market Types: Energy, Ancillary services and Transmission markets - Market Power - Stranded costs – Key components in power market operation

UNIT II DEMAND AND PRICE FORECASTING 9

Short Term Load Forecasting – Application of Load forecasting – Factors affecting load forecasting – Load forecasting categories - Electricity Price Forecasting –Electricity price basics – Electricity price volatility – Categorization of price forecasting – Factors considered in price Forecasting – Electricity Price simulation module- simulation example- Price forecasting module based on ANN- ANN factors in price forecasting – Performance Evaluation of price forecasting Price volatility – Price spike analysis – Probability distribution of Electricity price-Applications of price forecasting – Application of price forecast to make generation schedule – Application of probability Distribution of price to asset valuation and risk analysis – application of probability distribution to options valuation – Application of conditional probability distribution of price on Load to forward price forecasting

UNIT III PRICE BASED UNIT COMMITMENT 9

Introduction – PBUC formulation – System constraints- Unit constraints – PBUC solution – solution without emission or fuel constraints- solution with emission and fuel constraints – discussion and solution methodology – Energy purchase – Derivation of steps for updating multipliers – Optimality condition – Additional features of PBUC – Different prices among buses – Variable fuel price as a function of fuel consumption – Application of Lagrangian augmentation – Bidding strategy based on PBUC

UNIT IV ELECTRICITY TRADING ,GENERATION ASSET VALUATION, RISK ANALYSIS -RISK MANAGEMENT 9

Introduction – Essence of Electric Energy trading – Framework: Qualifying factors – Derivative instruments of energy trading –Application of derivatives in energy trading – Portfolio management – Energy trading Hubs-Brokers in Electricity trading – Market Risk – Hedge – Sources of Electricity market risk –Counter party risk –Risk valuation in electricity trading -- Generation Assert valuation – Asset valuation – Value at Risk(VaR)-Application of VaR to Asset valuation – VaR for Generation asset valuation-Generation capacity valuation

UNIT V TRANSMISSION CONGESTION MANAGEMENT AND PRICING 9

Introduction – Transmission cost allocation methods – Postage stamp rate method – contract path method – MW-Mile method – Unused transmission capacity method – MVA – Mile method – Counter Flow method – Distribution factor method – AC power flow method – Tracing methods- Comparison of cost allocation methods – Examples for transmission cost allocation methods – Locational Marginal Pricing (LMP) – Firm Transmission Rights(FTR) – Congestion Management – FTR Auction - Zonal congestion management – A comprehensive transmission pricing scheme – outline – prioritization of transmission dispatch – Calculation of transmission usage and congestion charges and FTR credits

TOTAL : 45 PERIODS

OUTCOMES:

- This subject gives an insight on the various electricity market models and provide knowledge about restructuring of power system.

REFERENCES

1. Mohammad Shahidehpour, Muwaffaq Almoush - Restructured Electrical Power Systems – Operation, Trading and Volatility – Marcel Dekker, Inc, NewYork
2. Mohammad Shahidehpour, Hatim Yamn, Zuyi LI – Market Operations in Electric Power Systems – Forecasting, Scheduling and Risk management – John Wiley & Sons, Inc, Publication.

PS7251 ADVANCED POWER SYSTEM PROTECTION L T P C
3 0 0 3

COURSE OBJECTIVES

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

UNIT I OVER CURRENT & EARTH FAULT PROTECTION 9

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

UNIT II TRANSFORMER & BUSBAR PROTECTION 13

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

UNIT III DISTANCE AND CARRIER PROTECTION OF TRANSMISSION LINES 9

Braw back of over – Current protection – Introduction to distance relay – Simple impedance relay – Reactance relay – Mho relays – Disadvantages – Quadrilateral Characteristics - Comparison of distance relay – Distance protection of a three – Phase line-reasons for inaccuracy of distance relay reach - Three stepped distance protection – Effect of Source impedance & Earthing – Effect of Power Swing - Need for carrier – Aided protection – Various options for a carrier - Coupling and trapping the carrier into the desired line section - Unit type carrier aided directional comparison relaying – Carrier aided distance schemes – Permissive Under reach & Over reach schemes - Acceleration of Zone II faults - Numerical example for a typical distance protection scheme for a transmission line.

UNIT IV GENERATOR PROTECTION 8

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

UNIT V SUBSTATION AUTOMATION 6

Introduction to Substation Automation – Topology – Hardware Implementation – Introduction to Digital Substation – Importance of Communications in Digital world – OSI Layer – Ethernet Communication – Introduction to Analog to Digital Transformation – Merging Units (MU) - Introduction to IEC 61850 – Advantages of IEC 61850.

TOTAL: 45 PERIODS

OUTCOME

- Learners will be able to understand the various schemes available in Transformer protection
- Learners will have knowledge on Overcurrent protection.
- Learners will attain knowledge about Distance and Carrier protection in transmission lines.
- Learners will understand the concepts of Bus bar protection.
- Learners will attain basic knowledge on substation automation.

TEXTBOOKS
1. Y.G. Paithankar and S.R Bhide, “Fundamentals of Power System Protection”, Prentice-Hall of India, 2003
2. Badri Ram and D.N. Vishwakarma, “Power System Protection and Switchgear”, Tata McGraw- Hill Publishing Company, 2002.

REFERENCES
1. P.Kundur, “Power System Stability and Control”, McGraw-Hill, 1993.
2. Protective Relaying for Power System II Stanley Horowitz,IEEE press , New York, 2008
3. Network Protection & Automation Guide, Edition May 2011 – Alstom Grid.
4. T.S.M. Rao, Digital Relay / Numerical relays, Tata McGraw Hill, New Delhi, 1989

PS7152	**POWER SYSTEM DYNAMICS**	**L T P C**
		3 0 0 3

COURSE OBJECTIVES
- To impart knowledge on dynamic modelling of a synchronous machine in detail
- To describe the modelling of excitation and speed governing system in detail.
- To understand the fundamental concepts of stability of dynamic systems and its classification
- To understand and enhance small signal stability problem of power systems.

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, Steady-state equivalent circuit, Computation of steady-state values, Equations of Motion: Swing Equation, calculation of inertia constant, Representation in system studies, Synchronous Machine Representation in Stability Studies: Simplifications for large-scale studies : Neglect of stator *p*□□□ terms and speed variations, Simplified model with amortisseurs neglected: two-axis model with amortisseur windings neglected, classical model.

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

UNIT V ENHANCEMENT OF SMALL SIGNAL STABILITY 9

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

TOTAL: 45 PERIODS

OUTCOMES

- Learners will be able to understand on dynamic modelling of synchronous machine.
- Learners will be able to understand the modeling of excitation and speed governing system for stability analysis.
- Learners will attain knowledge about stability of dynamic systems.
- Learners will understand the significance about small signal stability analysis with controllers.
- Learners will understand the enhancement of small signal stability.

TEXT BOOKS:

1. R.Ramunujam," Power System Dynamics Analysis and Simulation, PHI Learning Private Limited, New Delhi, 2009
2. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.

REFERENCES:

1. P. W. Sauer and M. A. Pai," Power System Dynamics and Stability", Stipes Publishing Co, 2007
2. 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.
3. P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press, Ames, Iowa, 1978.

HV7073 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY **L T P C 3 0 0 3**

OBJECTIVE:

- To provide fundamental knowledge on electromagnetic interference and electromagnetic compatibility.
- To study the important techniques to control EMI and EMC.
- To expose the knowledge on testing techniques as per Indian and international standards in EMI measurement.

UNIT INTRODUCTION 9

Definitions of EMI/EMC -Sources of EMI- Intersystems and Intrasystem- Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation- typical noise path- EMI predictions and modeling, Cross talk - Methods of eliminating interferences.

UNITII GROUNDING AND CABLING 9

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

UNIT III BALANCING, FILTERING AND SHIELDING 9

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

UNIT IV EMI IN ELEMENTS AND CIRCUITS 9

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

UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES 9

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

TOTAL : 45 PERIODS

OUTCOME:

- Awareness towards the EMI/EMC in elements and circuits.
- Ability to design and analyze the filtering circuits for the reduction of EMI
- To design and implement the test setup

REFERENCES

1. V.P. Kodali, "Engineering Electromagnetic Compatibility", S. Chand, 1996.
2. Henry W.Ott, " Noise reduction techniques in electronic systems", John Wiley & Sons, 1989.
3. Bernhard Keiser, "Principles of Electro-magnetic Compatibility", Artech House, Inc. (685 canton street, Norwood, MA 020062 USA) 1987.
4. Bridges, J.E Milleta J. and Ricketts.L.W., "EMP Radiation and Protective techniques", John Wiley and sons, USA 1976.
5. William Duff G., & Donald White R. J, "Series on Electromagnetic Interference and Compatibility", Vol.
6. Weston David A., "Electromagnetic Compatibility, Principles and Applications", 1991.

PW7004 **INTEGRATED ENERGY SYSTEMS** **LT P C**
3 0 0 3

COUSE OBJECTIVE:

- To understand the modelling of integrated energy systems
- To study the optimal design technique of hybrid energy systems
- To study the system aspects of integration of various power generation

UNIT I ENERGY CONSUMPTION PATTERN 9

Projection of energy demands – Possible substitution of conventional sources – Modern technological options – Introduction to hybrid and integrated energy systems – Total energy concept and waste heat utilization.

UNIT II MODELING OF INTEGRATED ENERGY SYSTEMS 9

Load matching and scheduling – Various possibilities to build hybrid systems – Problems associated with integrated energy systems – Performance analysis.

UNIT III OPTIMAL DESIGN OF HYBRID ENERGY SYSTEMS 9

Special optimization techniques applicable – Energy economics and cost optimization of integrated energy systems – Sample problems and case studies.

UNIT IV INTEGRATION OF VARIOUS POWER GENERATION SYSTEMS 9

Feasibility studies – Site selection – Related social, economic and technical problems – Special role of wind and biogas systems – Future prospects and case studies.

UNIT V SYSTEM ASPECTS OF INTEGRATION 9

Voltage effects, thermal effects, fault level. Islanding - Stand Alone Systems: Network voltage and system efficiency, Energy storage methods, Lead-Acid Batteries, Battery charger, case studies of stand alone system.- Hybrid Energy Systems and its economic evaluation - Mathematical modeling of Integrated Energy Systems - Technological aspects of power electronic systems connection to the grid

TOTAL: 45 PERIODS

OUTCOME:

- This course provide knowledge about modelling of hybrid energy system and integration of various power generation systems into the grid.

REFERENCES

1. P. R. Shukla, T. K. Moulik, S. Modak and P. Deo; Strategic Management of Energy Conservation,Oxford & IBM Publishing Co., 1993.
2. W. R. Murthy and G. McKay; Energy Management, Butherworth Heinemann, 2001.
3. S. S. Rao; Textbook on Engineering Optimization – Theory and Practice, 3rd Edition, J. Wiley, 1996.
4. R. D. Begamudre: Energy Conversion Systems, New Age Int. Pub., 2000.
5. D. Merick and R. Marshall; Energy, Present and Future Options, Vol. I & Vol. II, J. Wiley, 1981.

ET7074 **MEMS TECHNOLOGY** **L T P C**
3 0 0 3

Course objectives

- To teach the students properties of materials ,microstructure and fabrication methods.
- To teach the design and modeling of Electrostatic sensors and actuators.
- To teach the characterizing thermal sensors and actuators through design and modeling
- To teach the fundamentals of piezoelectric sensors and actuators through exposure to different MEMS and NEMS devices
- To involve Discussions/ Practice/Exercise onto revising & familiarizing the concepts acquired over the 5 Units of the subject for improved employability skills

UNIT I MICRO-FABRICATION, MATERIALS AND ELECTRO-MECHANICAL CONEPTS 9

Overview of micro fabrication – Silicon and other material based fabrication processes – Concepts: Conductivity of semiconductors-Crystal planes and orientation-stress and strain-flexural beam bending analysis-torsional deflections-Intrinsic stress- resonant frequency and quality factor.

UNIT II ELECTROSTATIC SENSORS AND ACTUATION 9

Principle, material, design and fabrication of parallel plate capacitors as electrostatic sensors and actuators-Applications

UNIT III THERMAL SENSING AND ACTUATION 9

Principle, material, design and fabrication of thermal couples, thermal bimorph sensors, thermal resistor sensors-Applications.

UNIT IV PIEZOELECTRIC SENSING AND ACTUATION 9

Piezoelectric effect-cantilever piezo electric actuator model-properties of piezoelectric materials-Applications.

UNIT V CASE STUDIES 9

Piezoresistive sensors, Magnetic actuation, Micro fluidics applications, Medical applications, Optical MEMS.-NEMS Devices

Note :Discussions/Exercise/Practice on Workbench : on the basics /device model design aspects of thermal/peizo/resistive sensors etc.

TOTAL : 45 PERIODS

Course Outcome:

- The learning process delivers insight onto design of micro sensors, embedded sensors & actuators in power aware systems like grid
- Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design.

REFERENCES

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
2. Marc Madou , “Fundamentals of microfabrication”,CRC Press, 1997.
3. Boston , “Micromachined Transducers Sourcebook”,WCB McGraw Hill, 1998.
4.M.H.Bao “Micromechanical transducers :Pressure sensors, accelerometers and gyroscopes”, Elsevier, Newyork, 2000.

HV7072 DESIGN OF SUBSTATIONS L T P C
3 0 0 3

OBJECTIVE:

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

UNIT I INTRODUCTION TO AIS AND GIS 9

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

UNIT II MAJOR EQUIPMENT AND LAYOUT OF AIS AND GIS 9

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

UNIT III INSULATION COORDINATION OF AIS AND GIS 9

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

UNIT IV GROUNDING AND SHIELDING 9

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

UNIT V FAST TRANSIENTS PHENOMENON IN AIS AND GIS 9

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

TOTAL : 45 PERIODS

OUTCOME:

- Awareness towards substation equipment and their arrangements.
- Ability to design the substation for present requirement with proper insulation coordination and protection against fast transients.

REFERENCES

1. Andrew R. Hileman, “Insulation coordination for power systems”, Taylor and Francis, 1999.
2. M.S. Naidu, “Gas Insulation Substations”, I.K. International Publishing House Private Limited, 2008.
3. Klaus Ragallar, “Surges in high voltage networks” Plenum Press,New York, 1980.
4. “Power Engineer’s handbook”, TNEB Association.
5. Pritindra Chowdhuri, “Electromagnetic transients in power systems”, PHI Learning Private Limited, New Delhi, Second edition, 2004.

6. “Design guide for rural substation”, United States Department of Agriculture, RUS Bulletin, 1724E-300, June 2001.
7. AIEE Committee Report, “Substation One-line Diagrams,” AIEE Trans. on Power Apparatus and Systems, August 1953
8. Hermann Koch , “Gas Insulated Substations”, Wiley-IEEE Press,2014

PS7073 OPTIMISATION TECHNIQUES L T P C
3 0 0 3

COURSE OBJECTIVES

- To introduce the different optimization problems and techniques
- To study the fundamentals of the linear and non-linear programming problem.
- To understand the concept of dynamic programming and genetic algorithm technique

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.

TOTAL : 45 PERIODS

OUTCOMES

- Students will learn about different classifications of optimization problems and techniques.

- Students will attain knowledge on linear programming concepts
- Students will understand the application of non- linear programming in optimization techniques
- Students will understand the fundamental concepts of dynamic programming
- Students will have knowledge about Genetic algorithm and its application to optimization in power system.

TEXT BOOKS

1. S.S. Rao ,"Optimization – Theory and Applications", Wiley-Eastern Limited, 1984.
2. G.Luenberger," Introduction of Linear and Non-Linear Programming" , Wesley Publishing Company, 2011.

REFERENCE BOOKS:

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.

PS7075 WIND ENERGY CONVERSION SYSTEM LT P C
3 0 0 3

COURSE OBJECTIVES

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

UNIT I INTRODUCTION 9

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

UNIT II WIND TURBINES 9

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

UNIT III FIXED SPEED SYSTEMS 9

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

UNIT IV VARIABLE SPEED SYSTEMS 9

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

UNIT V GRID CONNECTED SYSTEMS 9

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

TOTAL: 45 PERIODS

OUTCOMES

- Students will attain knowledge on the basic concepts of Wind energy conversion system.
- Students will have the knowledge of the mathematical modelling and control of the Wind turbine
- Students will develop more understanding on the design of Fixed speed system
- Students will study about the need of Variable speed system and its modelling.
- Students will learn about Grid integration issues and current practices of wind interconnections with power system.

TEXT BOOKS

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990
2. S.N.Bhadra, D.Kastha,S.Banerjee,"Wind Electrical Sytems",Oxford University Press,2010.

REFERENCES

1. Ion Boldea, "Variable speed generators", Taylor & Francis group, 2006.
2. E.W.Golding "The generation of Electricity by wind power", Redwood burn Ltd., Trowbridge,1976.
3. N. Jenkins," Wind Energy Technology" John Wiley & Sons,1997
4. S.Heir "Grid Integration of WECS", Wiley 1998.

PS7072 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION L T P C
3 0 0 3

COURSE OBJECTIVES

- To impart knowledge on operation, modelling and control of HVDC link.
- To perform steady state analysis of AC/DC system.
- To expose various HVDC simulators.

UNIT I DC POWER TRANSMISSION TECHNOLOGY 6

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 **12**

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 – Unified, Sequential and Substitution of power injection method.

UNIT V SIMULATION OF HVDC SYSTEMS **9**

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

TOTAL :45 PERIODS

OUTCOME

- Students will develop understanding on DC power transmission technologies,
- Students will study about HVDC converters and HVDC system control,
- Students will develop understanding on multi-terminal DC system,
- Students will attain knowledge on AC/DC power flow analysis,
- Students will study about modeling of HVDC systems and HVDC system simulation techniques.

TEXT BOOKS

1. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 1993
2. K.R.Padiyar, , “HVDC Power Transmission Systems”, New Age International (P) Ltd., New Delhi, 2002.

REFERENCES

1. J.Arrillaga, , “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 1983.
2. Erich Uhlmann, “ Power Transmission by Direct Current”, BS Publications, 2004.
3. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.

PE7072 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS LT P C
3 0 0 3

OBJECTIVES :

- To Provide knowledge about the stand alone and grid connected renewable energy systems.
- To equip with required skills to derive the criteria for the design of power converters for renewable energy applications.
- To analyse and comprehend the various operating modes of wind electrical generators and solar energy systems.
- To design different power converters namely AC to DC, DC to DC and AC to AC converters for renewable energy systems.
- To develop maximum power point tracking algorithms.

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 ocean, Biomass, Hydrogen energy systems : operating principles and characteristics of: Solar PV, Fuel cells, wind electrical systems-control strategy, operating area.

UNIT II ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION 9

Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG.

UNIT III POWER CONVERTERS 9

Solar: Block diagram of solar photo voltaic system : 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 IV ANALYSIS OF WIND AND PV SYSTEMS 9

Standalone operation of fixed and variable speed wind energy conversion systems and solar system-Grid connection Issues -Grid integrated PMSG and SCIG Based WECS-Grid Integrated solar system

UNIT V HYBRID RENEWABLE ENERGY SYSTEMS 9

Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PVMaximumPower Point Tracking (MPPT).

TOTAL : 45 PERIODS

OUTCOME:

- Ability to design grid connected/standalone renewable energy system employing embedded energy storage and MPPT strategy.

TEXT BOOK

1. S.N.Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009

REFERENCES:
1. Rashid .M. H “power electronics Hand book”, Academic press, 2001.
2. Rai. G.D, “Non conventional energy sources”, Khanna publishes, 1993.
3. Rai. G.D,” Solar energy utilization”, Khanna publishes, 1993.
4. Gray, L. Johnson, “Wind energy system”, prentice hall linc, 1995.
5. Non-conventional Energy sources B.H.Khan Tata McGraw-hill Publishing Company, New Delhi.

CO7071 CONTROL OF ELECTRICAL DRIVES **L T P C**
3 0 0 3

COURSE OBJECTIVES
- To introduce the PWM converters and their analysis.
- To educate on modeling of dc motor, drives and control techniques To educate on dynamic modeling of Induction motor drive.
- To educate on the V/f and vector control of Induction motor.
- To educate on generation of firing pulses and control algorithms in embedded platforms.

UNIT I POWER ELECTRONIC CONVERTERS FOR DRIVES 9
Power electronic switches-state space representation of switching converters-Fixed frequency PWM-variable frequency PWM- space vector PWM- Hysteresis current control-dynamic analysis of switching converters-PWM modulator model.

UNIT II CONTROL OF DC DRIVES 9
Modelling of DC machines-block diagram/transfer function-phase control-1phase/3phase converter fed DC drives- Chopper fed DC drives-four quadrant chopper circuit-closed loop control-speed control-current control-cascade control –constant torque/power operation-comparison of chopper/converter fed drives- techniques-merits/demits.

UNIT III ANALYSIS AND MODELLING OF INDUCTION MOTOR DRIVE 9
Basics of induction motor drive-classification – equivalent circuit- torque Vs slip characteristics-steady state performance- Dynamic modeling of induction motor, Three phase to two phase transformation-stator, rotor, synchronously rotating reference frame model.

UNIT IV CONTROL OF INDUCTION MOTOR DRIVE 9
VSI fed induction motor drives- waveforms for 1-phase, 3-phase Non-PWM and PWM VSI fed induction motor drives -principles of V/F control- principle of vector control-direct vector control-space vector modulation- indirect vector control .

UNIT V EMBEDDED CONTROL OF DRIVES 9
Generation of firing pulses- generation of PWM pulses using embedded processors-IC control of DC drives- fixed frequency/variable frequency/current control- V/F control using PIC microcontroller- vector control using embedded processors.

TOTAL : 45 PERIODS

REFERENCES

1. R.Krishnan, “Electric Motor Drives, Modeling, Analysis and Control” Prentice Hall of India, 2002.
2. Thyristor control of Electric drives, Vedam Subrahmanyam, Tata McGraw Hill, 1988
3. Ion Boldea & S.A.Nasar “ELECTRIC DRIVES”, CRC Press, 2006
4. Simon Ang, Alejandro Oliva “POWER SWITCHING CONVERTERS”, CRC Press, 2005
5. Buxbaum, A. Schierau, and K.Staughen, “A design of control systems for DC Drives”, Springer-Verlag, Berlin,1990.

PS7074 SOLAR AND ENERGY STORAGE SYSTEM **L T P C**
3 0 0 3

COURSE OBJECTIVES

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

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.

TOTAL : 45 PERIODS

OUTCOME

- Students will develop more understanding on solar energy storage systems
- Students will develop basic knowledge on standalone PV system
- Students will understand the issues in grid connected PV systems
- Students will study about the modelling of different energy storage systems and their performances
- Students will attain more on different applications of solar energy

TEXT BOOKS

1. Eduardo Lorenzo G. Araujo, Solar electricity engineering of photovoltaic systems, Progensa,1994.
2. Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, Applied Photovoltaics, 2007,Earthscan, UK.

REFERENCES:

1. Frank S. Barnes & Jonah G. Levine, Large Energy storage Systems Handbook , CRC Press, 2011.
2. Solar & Wind energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern, 1990
3. Solar Energy – S.P. Sukhatme, Tata McGraw Hill,1987.