M.Tech Programme
Electrical Engineering- Power System and Control
Curriculum and Scheme of Examinations

SEMESTER I

Code No.	Name of Subject	Credits	Hrs / week	End Sem Exam (hours)	Marks			Remarks
					Internal Continuous Assessment	End Semester Exam	Total	
EMA 1003	Advanced Mathematics for Power System Control	3	3	3	40	60	100	Of the 40 marks of internal assessment, 25 marks for tests and 15 marks for assignments. End sem exam is conducted by the University
EPC 1001	Computer Aided Power System Analysis	3	3	3	40	60	100	Do
EAC 1001	Power Conversion Techniques	3	3	3	40	60	100	Do
EMC 1002	Modeling of Electrical Machines	3	3	3	40	60	100	Do
EPC 1002	Operation and Control of Power System	3	3	3	40	60	100	Do
ECC 1003	Dynamics of Linear Systems	3	3	3	40	60	100	Do
EAC 1101	Power System Simulation Lab	1	2	-	100	-	100	No End Sem Examinations
EAC 1102	Seminar	2	2	-	100	-	100	Do
	TOTAL	21	22		440	360	800	7 Hours of Departmental assistance work

SEMESTER II

Code No.	Name of Subject	Credits	Hrs / week	End Sem Exam (hours)	Marks			Remarks
					Internal Continuous Assessment	End Semester Exam	Total	
EAC 2001	Advanced Power Electronic Sytems	3	3	3	40	60	100	Of the 40 marks of internal assessment, 25 marks for tests and 15 marks for assignments. End sem exam is conducted by the University
EPC 2002	Power System Dynamics and Control	3	3	3	40	60	100	Do
**	Stream Elective I	3	3	3	40	60	100	Do
**	Stream Elective II	3	3	3	40	60	100	Do
**	Department Elective	3	3	3	40	60	100	Do
ECC 2000	Research Methodology	2	2	3	40	60	100	End Sem Exam is conducted by the Individual Institutions
EAC 2101	Advanced Power System Lab	1	2	-	100		100	No End Sem Examinations
EAC 2102	Seminar	2	2	-	100		100	do
EAC 2103	Thesis – Preliminary Part I	2	2	-	100		100	do
	TOTAL	22	23	---	540	360	900	6 Hours of Departmental assistance work

SEMESTER II

List of Stream Elective -I

EAE 2001	Distributed Generation and Control
EPE 2001	Transient Analysis in Power System
EPE 2002	Flexible AC Transmission Systems
EPE 2004	Soft Computing Application to Power System
EME 2002	PWM Converters and Application

List of Stream Elective -II

EPC 2001	Digital Protection of Power System
ECC1002	Digital Control Systems
ECC2001	Optimal Control Theory
ECC2002	Non Linear Control Systems

List of Department Electives

EAD 2001	Deregulation in Power Systems
EPC 1003	Power Quality
EPD 2001	New and Renewable Source of Energy
EPD 2002	SCADA System and Application

SEMESTER III

Code No.	Name of Subject	Credit	Hrs / week	End Sem Exam hours	Marks			Remarks
					Continuous Assessment	End Semester Exam	Total	
**	Stream Elective III	3	3	3	40	60	100	End Sem Exam is conducted by the Individual Institutions
**	Stream Elective IV	3	3	3	40	60	100	Do
**	Non- Dept. (Interdisciplinary) Elective	3	3	3	40	60	100	Do
EAC 3101	Thesis – Preliminary – Part II	5	14	-	200		200	No End Sem Examinations
	TOTAL	14	23		320	180	500	6 Hours of Departmental assistance work

List of Stream Electives-III

EAE 3001 Power System Management

EAE 3002 Captive Power Systems

EAE 3003 Smart Grid Technology and Applications

EAE 3004 Control of Industrial Drives

EAE 3005 Voltage Stability Analysis in Power Systems

List of Stream Electives-IV

EAE 3006 Advanced Digital Signal Processing

EPE 3001 Distribution System Planning and Automation

EPE 3002 Power System Stability and Reliability

EPE 3003 EHV AC & DC Transmission System

EPE 3004 Static Var Controllers and Harmonic Filtering

EPE 3005 Power System Instrumentation

List of Interdisciplinary Electives

EPI 3001 Renewable Energy Sources and Technology

EPI 3002 Energy Auditing and Management

EAI 3001 Autonomous Power Systems

SEMESTER IV

Code No	Subject Name	Credits	Hrs/week	Marks				
				Continuous Assessment		University Exam		Total
				Guide	Evaluation Committee	Thesis Evaluation	Viva Voce	
EAC 4101	Thesis	12	21	150	150	200	100	600
	Total	12	21					8 Hours of Departmental assistance work

Note : 6 to 8 hours per week is for department assistance

SEMESTER I

EMA 1003 ADVANCED MATHEMATICS FOR POWER SYSTEM CONTROL 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course objective:

1. Introduce various optimization methods to enable students to apply them in practical problems
2. Equip the Students with a thorough understanding of vector spaces, probabilities, random process and queuing theory

Learning outcome:

Basic knowledge of vector spaces and optimization theory which are essential for higher studies and research in Engineering.

Module 1

Concepts of optimization: Statement of optimization problem - Classification -Engineering applications- Linear Programming- Graphical method- Simplex method -Duality- Sensitivity analysis - Transportation and assignment problems.

Nonlinear programming- Unconstrained optimization techniques-Direct search methods-Descent methods -Constrained optimization - Direct and Indirect methods - Kuhn tucker conditions.

Module2

Dynamic programming- Multistage decision process -Concept of sub optimization and Principle of optimality -Computational procedure

Advanced optimization techniques- Genetic Algorithm -Simulated annealing methods-Tabu Search – Particle swarm optimization – ant colony algorithm

Module 3

Vector Space: Vector space, subspace, linear independence of vectors - Dimension and basis (Definitions, theorems without proof and problems), linear transformations, Rank and nullity, Inner product, Norm of a vector, Orthogonal vectors, Gram Schmidt Orthogonalization process.

Probability and Random Processes: Gaussian processes, Discrete time Markov chains, Chapman-Kolmogorov Equations, classification of states, Steady State Probabilities, continuous - time Markov chain: State occupancy times, transition rates, Steady State Probabilities, Global balance equations, Application to Birth - death process and Queuing models (M/M/1 and M/M/c models with infinite capacity).

References:

1. Singiresu S Rao, "Engineering Optimization Theory and Practices, John Wiley & Sons, 1998.
2. Engineering optimization, Methods and Applications'-- G V Reklaitis, A Ravindran & K M Rajsdell
3. Alberto leon-Garcia, Probability and Random Processes for Electrical Engineering, Pearson, 2/e., 2009
4. S M Ross, Introduction to Probability Models, Elsevier, 10th ed 2009.
5. Sundarapandian, Probability Statistics and Queuing Theory, PHI, 2009.
6. T Veerarajan, Probability and Random Process, Tata McGraw Hill, 3rd ed., 2011
7. Peter V. O. Niel, *'Advanced Engineering Mathematics'*, 4th edition, Brooks Cole Publications.
8. Greenberg, *'Advanced Engineering Mathematics* Pearson Edn.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPC 1001 COMPUTER AIDED POWER SYSTEM ANALYSIS 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective

1. To introduce computer applications in analysis of power systems
2. To understand the solution methods and techniques involved in power system studies

Course Outcome

A better understanding of the merits and demerits of critical analytical solution methods which are the basis for valid techniques in solving power system problems

Module 1

Review of solution of Linear System of equations by Gauss Jordan method, Gauss elimination, LU factorization and LDU factorization**.**

Load Flow Studies: Overview of Gauss, Gauss- Seidel and Newton Raphson Methods, Decoupled Load Flow, Fast Decoupled Load Flow, DC load flow, Three phase Load Flow and Harmonic Load flow. Sparsity techniques, Triangular factorization and Optimal ordering.

Incorporation of FACTS devices in Load Flow: Static Tap Changing, Phase Shifting (PS), Static Var Compensator (SVC), Thyristor Controlled Series Compensator (TCSC) and Unified Power Flow Controller (UPFC)

Module 2

Elementary linear graph theory –Incidence and network matrices. Development of network matrices from Graph theoretic approach, Building algorithm for Bus impedance matrix, Modification of Z_{BUS} matrix due to changes in primitive network.

Short Circuit studies – Types of Faults – Short circuit study of a large power system – Algorithm for calculating system conditions after fault – three short circuit, three phase to ground, double line to ground, line to line and single line to ground fault.

Module 3

State estimation – least square and weighted least square estimation methods for linear and non-linear systems. Static state estimation of power systems- injections only and line only algorithms, Treatment of bad data – detection, identification and suppression of bad data.

Contingency Analysis- adding and removing multiple lines, Analysis of single and multiple contingencies, Contingency Analysis by DC model, System reduction for contingency and fault studies

References

1. Power System Analysis- John J. Grainger, William D. Stevenson, Jr., Tata McGraw-Hill Series in ECE.
2. Modern Power system Analysis, 3rd Edition- I. J. Nagrath and D. P. Kothari, Tata McGraw Hill, 1980
3. Computer modeling of Electrical Power Systems - J. Arriliga and N. R. Watson, Wiley, 2001
4. Computer methods in power system analysis- G.W. Stagg and El-Abiad McGraw Hill, 1968
5. Power System Analysis- Hadi Saadat, McGraw Hill
6. Power System Harmonic Analysis - Jos Arrillaga, Bruce C. Smith, Neville R. Watson, Alan Wood, John Wiley and Son, 1997
7. Computational methods for large sparse power systems analysis: An object oriented approach, S A Soman, S A Khaparde, Shubha Pandit, Kluwer academic publishers
8. Computer Aided Power System Analysis- G. L. Kusic, Prentice Hall, 1986
9. Large networks by matrix methods, H E Brown, John Wiley

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAC 1001 POWER CONVERSION TECHNIQUES 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks	

Course Objective:
To Familiarize various Power Electronic conversion techniques

Course Outcome
A better understanding of the merits and demerits of critical analytical solution methods which are the basis for valid techniques in solving power system problems

Module 1

AC voltage controllers: Analysis of single-phase ac voltage controller with R and RL load, Performance parameters, Sequential control of single-phase ac voltage controllers.

DC-DC converters: Buck, boost, buck-boost and C'uk Topologies-Representation with ideal switches, Steady state analysis in continuous conduction mode using inductor volt-sec balance-- current and voltage ripples. Design relations for inductor and capacitors. Discontinuous Conduction Mode operation of basic buck and boost converter-Isolated dc-dc converters: Steady-state analysis of fly back, forward, push-pull and bridge topologies.

Module 2

Switched Mode Inverters: Topologies of single-phase half-bridge, full-bridge and three-phase bridge Voltage Source Inverters-Representation using ideal switches- stepped wave and PWM operation- Sine-Triangle PWM-Selective Harmonic Elimination--Space Vector PWM-Evaluation of dwell times- Principles of Current-Controlled VSI- Hysteresis control and PWM current control. Current Source Inverters: Analysis of capacitor commutated single phase CSI feeding resistive and pure-inductor loads.

Module 3

Resonant Converters - Second-Order Resonant Circuits - Load Resonant Converters - Resonant Switch Converters – Resonant DC-Link Converters with ZVS

Series-Resonant Inverters: Voltage-Source Series-Resonant Inverters - Voltage-Source Parallel-Resonant Inverters - Voltage-Source Series–Parallel-Resonant Inverters

Resonant DC-Link Inverters : The Resonant DC-Link Inverter - The Parallel-Resonant DC-Link Inverter - Current Research Trends

Auxiliary Resonant Commutated Pole Inverters: Losses in Hard-Switched Inverters - Analysis of ARCP Phase Leg - Analysis of ARCP H-Bridge - Analysis of ARCP Three-Phase Inverter

References

1. Ned Mohan, *et. al.*, "*Power Electronics: Converters, Design and Applications,*" Wiley
2. V. Ramanarayanan, "*Course Notes on Switched Mode Power Converters,* "Department of Electrical Engineering, Indian Institute of Science, Bangalore
3. G. K. Dubey, *et.al.*, "*Thyristorised Power Controllers,*" New Age International
4. John Vithayathil, "*Power Electronics: Principles and Applications*", Tata McGraw Hill
5. Bin Wu, "*High Power Converters and AC Drives,*" IEEE Press, Wiley Interscience, 2006.
6. L. Umanand, "*Power Electronics: Essentials and Applications,*" Wiley, 2009
7. Thimothy L. Skvarenina, "*The Power electronics handbook",* CRC press*, 2002*

Structure of the question paper
The question paper contains three questions from each module out of which two questions are to be answered by the student.

EMC 1002 MODELING OF ELECTRICAL MACHINES 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: To develop the basic elements of generalized theory and to derive the general equations for voltage and torque of all type of rotating machines and to deal with their steady state and transient analysis

Module 1

Unified approach to the analysis of electrical machine performance - per unit system - basic two pole model of rotating machines- Primitive machine -special properties assigned to rotor windings - transformer and rotational voltages in the armature voltage and torque equations resistance, inductance and torque matrix. Transformations - passive linear transformation in machines- invariance of power - transformation from three phase to two phase and from rotating axes to stationary axes-Park's transformation

Module 2

DC Machines: Application of generalized theory to separately excited, shunt, series and compound machines. Steady state and transient analysis, transfer functions. Sudden short circuit of separately excited generator, sudden application of inertia load to separately excited dc motor.

Synchronous Machines: Synchronous machine reactance and time constants-Primitive machine model of synchronous machine with damper windings on both axes. Balanced steady state analysis-power angle curves. Transient analysis- sudden three phase short circuit at generator terminals - armature currents and torque. - Transient power angle curve .

Module 3

Induction Machines: Primitive machine representation- Steady state operation-Equivalent circuit-Double cage rotor representation - Equivalent circuit. Single phase induction motor- Voltage and Torque equations.

References

1. P.S.Bhimbra, '*Generalized theory of electrical machines* ', Khanna Publishers, 2002
2. Charles V.Johnes, '*Unified theory of electrical machines* '.
3. Adkins and Harley , '*General theory of ac machines*'.
4. C. Concordia, '*Synchronous Machines*'.
5. M.G. Say, '*Introduction to Unified theory of electrical machines*'
6. E W.Kimbark, '*Power System Stability Vol. II P*'.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPC 1002 OPERATION AND CONTROL OF POWER SYSTEM 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: Objective of the course is to make the students aware the importance of Economic operation as well as control of power system.

Module 1

Introduction-Review of Thermal units.-The Lambda iteration method-First order gradient method base point and participation factors.

Generation with limited supply-Take or pay fuel contract-composite generation production cost function- solution of gradient search techniques. Hard limits and slack variables

Module 2

Hydro-thermal coordination-Long range and short range scheduling- Hydro-electric plant models- scheduling problems types of scheduling problems. Scheduling energy -short-term hydrothermal scheduling problem- Pumped storage hydro plants- pumped storage hydro scheduling λ-γ iteration.

Inter change evaluation and power pools-Economy interchange evaluation with unit commitments. Types of interchange. Energy banking-power pools. Power system security-system monitoring-contingency analysis- security constrained optimal power flow- Factors affecting power system security. State estimation in power system-Introduction

Module 3

Control of generation-Automatic Generation control Review-AGC implementation - AGC features -Modeling exercise using SIMUL1NK. AGC with optimal dispatch of Generation- Voltage control-AGC including excitation system.

MVAR control - Application of voltage regulator – synchronous condenser – transformer taps – static VAR compensators

References

1. *Allen J.Wood and Wollenberg B.F., „Power Generation Operation and control", John Wiley & Sons, Second Edition,1996.*
2. S S. Vadhera. *'Power system Analysis and stability'*, Khanna Publishers
3. *Kirchmayer L.K., „Economic Control of Interconnected Systems", John Wiley & Sons, 1959.*
4. *Nagrath, I.J. and Kothari D.P., "Modern Power System Analysis", TMH, New Delhi, 2006.*
5. A Montieelli., 'State *Estimation in Electric power system-A Generalised Approach*'
6. Ali Abur & Antonio Gomez Exposito, *'Power system state estimation-Theory and Implementation[1],* Marcel Dekker Inc.
7. Hadi Sadat, *'Power system Analysis*'- Tata McGraw Hill
8. Recent literature.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

ECC1003 DYNAMICS OF LINEAR SYSTEMS 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3

Internal Assessment : 40 Marks.

End semester Examination: 60 Marks

Course Objectives

1. To provide a strong foundation on classical and modern control theory.
2. To provide an insight into the role of controllers in a system.
3. To design compensators using classical methods.
4. To design controllers in the state space domain.
5. To impart an in depth knowledge in observer design.

Learning Outcomes

Upon successful completion of this course, students will be able

1. To analyse a given system and assess its performance.
2. To design a suitable compensator to meet the required specifications.
3. To design and tune PID controllers for a given system.
4. To realise a linear system in state space domain and to evaluate controllability and observability.
5. To design a controller and observer for a given system and evaluate its performance.

Module 1

Design of feedback control systems- Approaches to system design-compensators-performance measures - cascade compensation networks-phase lead and lag compensator design using both Root locus and Bode plots-systems using integration networks, systems with pre-filter, PID controllers-effect of proportional, integral and derivative gains on system performance, PID tuning , integral windup and solutions.

Module 2

State Space Analysis and Design- Analysis of stabilization by pole cancellation - Canonical realizations - Parallel and cascade realizations - reachability and constructability - stabilizability - controllability - observability -grammians. Linear state variable feedback for SISO systems, Analysis of stabilization by output feedback-modal controllability-formulae for feedback gain -significance of controllable Canonic form-Ackermann's formula- feedback gains in terms of Eigen values - Mayne-Murdoch formula - Transfer function approach - state feedback and zeros of the transfer function - non controllable realizations and stabilizability -controllable and uncontrollable modes - regulator problems - non zero set points - constant input disturbances and integral feedback.

Module 3

Observers: Asymptotic observers for state measurement-open loop observer-closed loop observer-formulae for observer gain - implementation of the observer - full order and reduced order observers - separation principle - combined observer - controller – optimality criterion for choosing observer poles - direct transfer function design procedures - Design using polynomial equations - Direct analysis of the Diophantine equation.

MIMO systems: Introduction, controllability, observability, different companion forms.

References

1. Thomas Kailath. “Linear System”, Prentice Hall, Inc. Eaglewood Cliffs. NJ. 1998
2. Benjamin C Kuo, “Control Systems”, Tata McGraw Hill, 2002
3. M Gopal, “Control Systems-Principles and Design”, Tata McGraw Hill
4. Richard C Dorf & Robert H Bishop, “Modern Control Systems”, Addison Wesley, 8th Edition, 1998
5. Gene K Franklin & J David Powell, “Feedback Control of Dynamic Systems”, Addison -Wesley, 3rd Edition
6. Friedland B, “Control System Design: An Introduction to State Space Methods”, McGraw Hill, NY 1986
7. M R Chidambaram and S. Ganapathy, “An Introduction to the Control of Dynamic Systems”, Sehgal Educational Publishers, 1979
8. C.T. Chen, “Linear system theory and Design”, Oxford University Press, New York, 1999

Structure of the question paper

For the end semester examination the question paper consists of at least 60% design problems and derivations. The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAC 1101 POWER SYSTEM SIMULATION LABORATORY 0-0-2-1

Structure of the course

Practical	:2Hrs Week	Credits: 1
Internal Assessment	:50 Marks.	
End semester Examination	:NIL	

1. Load flow studies – IEEE 5 bus system, IEEE 14 bus system, IEEE 30 bus systems.
2. Short circuit studies and transient stability studies.
3. Voltage Instability Analysis.
4. Harmonic Analysis
5. Economic Load Dispatch with thermal power plants.
5. Economic Load Dispatch with Hydro thermal power plants.
7. Simulation of Facts controllers
8. Simulation of single -area and Two -area Systems.
9. Load forecasting and unit commitment
10. Simulation of IGBT inverters.
11. Simulation of thyristor converters.

In addition to the above, the Department can offer a few other experiments
Minimum of 10 experiments are to be conducted

EAC 1102 SEMINAR

Structure of the Course Credits: 2

Seminar	: 2 hrs/week
Internal Continuous Assessment	: 100 Marks

The student is expected to present a seminar in one of the current topics in Power System and Control related areas. The student will undertake a detailed study based on current journals, published papers, books, on the chosen subject and submit seminar report at the end of the semester.

Marks:

Report Evaluation	: 50
Presentation	: 50

SEMESTER II

EAC 2001 ADVANCED POWER ELECTRONIC SYSTEMS 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks

Course Objective:
To introduce various advanced power electronics systems and various applications of Power Electronics in power system

Course Outcome
A better understanding of the various advancements and applications of power electronics in various fields

Module 1

Power electronics application in HVDC: Pulse number, Converter configuration, Analysis of Graetz circuit, Bridge characteristics, 12 pulse converter Principles of DC Link control-Converter control characteristics-System control, Firing angle control- Current and extinction angle control, DC link power control, Reactive power control and VAR sources, MTDC system
Power electronic control in distributed generation

Module 2
Power Quality conditioners – shunt and series compensators-DStatcom-Dynamic voltage restorer-unified power quality conditioners-case studies.

Control Methods for Power Converters: Introduction - Power Converter Control using State-Space Averaged Models - Sliding-Mode Control of Power Converters - Fuzzy Logic Control of Power Converters

Module 3

Microprocessors & Digital ICs for Control of Power Electronics and Drives: Introduction, Microcomputer control of Power Electronic Systems, Real time control using microcomputers, microcontrollers, advanced microprocessor for control of Power Electronic Systems, ASICS for control of Power Electronic Systems.
Design of Micro-processor Based control System, Development tools Applications: Digital control of permanent magnet synchronous motor drive for Electric vehicle propulsion.

References

1. Ned Mohan, *et. al.*, "*Power Electronics: Converters, Design and Applications,*" Wiley
2. V. Ramanarayanan, "*Course Notes on Switched Mode Power Converters,* "Department of Electrical Engineering, Indian Institute of Science, Bangalore
3. G. K. Dubey, *et.al.*, "*Thyristorised Power Controllers,*" New Age International
4. John Vithayathil, "*Power Electronics: Principles and Applications*", Tata McGraw Hill
5. Bin Wu, "*High Power Converters and AC Drives,*" IEEE Press, Wiley Interscience, 2006.
6. L. Umanand, "*Power Electronics: Essentials and Applications,*" Wiley, 2009
7. Thimothy L. Skvarenina, "*The Power electronics handbook*", CRC press, *2002*
8. Bimal K.Bose, "Power Electronics & Variable Frequency Drives", IEEE Press, 2000, Standard Publishers and Distributor, Delhi.
9. Bimal K.Bose, "Microcomputer Control of Electric Drives (Part I)", IEEE Press, 1987.

Structure of the question paper
The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPC 2002 POWER SYSTEM DYNAMICS AND CONTROL 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: To introduce various types of small signal stability problems that will encounter in power systems and also to introduce means to overcome them

Module 1

Concept of Power system stability-Types of stability-Classical model of single machine connected to infinite bus and a multi machine system-mathematical modeling of power system elements for stability studies-Synchronous machines. Excitation systems and Prime mover controllers-Transmission lines-Loads-HVDC and FACTS devices

Module2

Small Signal Analysis-Fundamental concepts of Stability of Dynamic Systems: State Space representation-Linearization-Eigen properties of state matrix-Small Signal Stability of Single Machine Infinite Bus(SMlB) System-Heffron-Phillips constants-Effects on Excitation system -Block diagram representation with exciter and AVR-Power System Stabiliser(PSS): State matrix including PSS-Small Signal Stability of Multi Machine Systems-Special Techniques for analysis of very large systems: Analysis of Essentially Spontaneous Oscillations in Power Systems(AESOPS) algorithms-Modified Arnoldi Method(MAM), Characteristics of Small Signal Stability Problems: local problems and global problems-Small Signal Stability Enhancement: Using Power System Stabilisers-Supplementary control of Static Var Compensators-Supplementary Control of HVDC transmission links-Inter area oscillations

Module 3

Sub synchronous Resonance-Turbine-Generator torsional Characteristics-Torsional interaction with Power System Controls-Sub synchronous resonance-Impact of network switching disturbances-Torsional interaction between closely coupled units-Hydro generator torsional characteristics

References:

1. Anderson and Fourd , *'Power System Control and Stability"* , Galgotia Publications, 1981
2. K R Padiyar, *'Power System Dynamics'*, 2nd Edition, B.S. Publishers, 2003
3. P Kundur, *'Power system Stability and Control'*, McGraw-Hill Inc., 1994
4. P W Sauer & M A Pai, *'Power System Dynamics and Stability*, Pearson, 2003
5. Olle I Elgerd, *'Electric Energy Systems Theory an Introduction'*, 2nd Edition, McGraw-Hill, 1983
6. E W Kimbark, *'Power System Stability'*, Wiley & IEEE Press, 1995
7. Yao-nan-Yu, *'Electric Power Systems Dynamics'*, Academic Press, 1983

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

ECC2000 RESEARCH METHODOLOGY 2-0-0-2

Structure of the course

Credits: 2

Lecture	: 2 hrs/week
Internal Assessment	: 40 Marks
End semester Examination	: 60 Marks

Course Objective

6. To formulate a viable research question
7. To distinguish probabilistic from deterministic explanations
8. To analyze the benefits and drawbacks of different methodologies
9. To understand how to prepare and execute a feasible research project

Learning Outcomes

Upon successful completion of this course, students will be able to understand research concepts in terms of identifying the research problem, collecting relevant data pertaining to the problem, to carry out the research and writing research papers/thesis/dissertation.

Module I

Introduction to Research Methodology - Objectives and types of research: Motivation towards research - Research methods *vs.* Methodology. Type of research: Descriptive *vs.* Analytical, Applied *vs.* Fundamental, Quantitative *vs.* Qualitative, and Conceptual *vs.* Empirical.
Research Formulation - Defining and formulating the research problem -Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem. Literature review: Primary and secondary sources - reviews, treatise, monographs, patents. Web as a source: searching the web. Critical literature review - Identifying gap areas from literature review - Development of working hypothesis. (15 Hours)

Module II

Research design and methods: Research design - Basic Principles- Need for research design — Features of a good design. Important concepts relating to research design: Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction. Development of Models and research plans: Exploration, Description, Diagnosis, Experimentation and sample designs. Data Collection and analysis: Execution of the research - Observation and Collection of data - Methods of data collection - Sampling Methods- Data Processing and Analysis strategies - Data Analysis with Statistical Packages - Hypothesis-Testing -Generalization and Interpretation. (15 Hours)

Module III

Reporting and thesis writing - Structure and components of scientific reports -Types of report - Technical reports and thesis - Significance - Different steps in the preparation, Layout, structure and Language of typical reports, Illustrations and tables, Bibliography, referencing and footnotes. Presentation; Oral presentation - Planning - Preparation -Practice - Making presentation - Use of audio-visual aids - Importance of effective communication.
Application of results of research outcome: Environmental impacts –Professional ethics - Ethical issues -ethical committees. Commercialization of the work - Copy right - royalty - Intellectual property rights and patent law - Trade Related aspects of Intellectual Property Rights - Reproduction of published material - Plagiarism - Citation and acknowledgement - Reproducibility and accountability.

References

1. C. R. Kothari, *Research Methodology*, Sultan Chand & Sons, New Delhi,1990
2. Panneerselvam, *Research Methodology*, Prentice Hall of India, New Delhi, 2012.
3. J. W. Bames, *Statistical Analysis for Engineers and Scientists,* Tata McGraw-Hill, New York.
4. Donald Cooper, *Business Research Methods,* Tata McGraw-Hill, New Delhi.
5. Leedy P. D., *Practical Research: Planning and Design*, McMillan Publishing Co.
6. Day R. A., *How to Write and Publish a Scientific Paper*, Cambridge University Press, 1989.
7. Manna, Chakraborti, *Values and Ethics in Business Profession*, Prentice Hall of India, New Delhi, 2012.
8. Sople, *Managing Intellectual Property: The Strategic Imperative*, Prentice Hall of India, New Delhi, 2012.

EAC 2101 ADVANCED POWER SYSTEMS LAB 0-0-2-1

Structure of the course

Lecture : 2Hrs /Week Credits: 1
Internal Assessment : 50 Marks.
End semester Examination : Nil

1. Load flow studies incorporating FACTS devices
2. Three phase unbalanced Load flow analysis, Short Circuit and Transient stability Studies
3. Optimal Load Flow
4. Load Flow analysis using Neural Network
5. Simulation of HVDC systems
6. State Estimations using Neural Network
7. Contingency Analysis using Neural Network
8. Power system Security using Neural Network
9. Fuzzy Logic load flow
10. Fuzzy Logic based AGC, Single area system, Two area system
11. Fuzzy Logic based small signal stability analysis
12. Study of load frequency control problem of (i) uncontrolled and (ii) controlled cases- Economic Dispatch of (i) Thermal Units and (ii) Thermal Plants using Conventional and ANN & GA algorithms
13. Application of GA for optimal capacitor placement in distribution systems
14. Load flow in distribution systems
15. Network reconfiguration in distribution systems
16. Tracing power flow in transmission systems
17. Generation and transmission loss allocation in deregulated environment
18. Modelling of a fuel cell power plant for standalone application and grid interface.
19. Micro-Grid Simulation during Grid-Connected and Islanded Modes of Operation

In addition to the above, the Department can offer a few experiments.

Minimum of 10 experiments are to be conducted

EAC 2102 SEMINAR

Structure of the Course

Duration	: 2 hrs/week	Credits: 2
Continuous Assessment	: 100 Marks	

The student is expected to present a seminar in one of the current topics in the stream of specialisation. The student will undertake a detailed study based on current published papers, journals, books on the chosen subject, present the seminar and submit seminar report at the end of the semester.

Distribution of marks

Seminar Report Evaluation	- 50 marks
Seminar Presentation	- 50 marks

EAE 2001 DISTRIBUTED GENERATION AND CONTROL

3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Description: This course focuses on the new renewable energy based electric energy generation technologies and their integration into the power grid. The principles of new energy based distributed generation technologies: solar, wind, and fuel cells. Interconnection of distributed generation sources to power distribution grid. Economic aspects of distributed generation.

Course objectives

1. Have a working knowledge of the emerging power generation technologies such as photovoltaic arrays, wind turbines, and fuel cells.
2. Model renewable electrical energy systems for analysis and design.
3. Calculate the basic performance parameters of these systems, such as efficiency and cost.
4. Perform basic assessment and design of a renewable electrical energy system for a given application.
5. Determine the requirements for interconnecting a renewable electrical energy system to the utility electric power grid.

Module 1

Distributed Generation Definition, Distributed generation advantages, challenges and needs.- Non conventional and renewable energy sources-Wind Power- wind turbine and rotor types, wind speed –power curve, power coefficient, tip speed ratio, wind energy distribution, environmental impact. Photovoltaic and Thermo-solar power –Solar cell technology, Photovoltaic power characteristics and Thermo-solar power generation.- Biomass Power, Fuel cells types, types of Tidal power generation schemes, mini and micro hydro power schemes, and Micro turbines for DG, bulb and tubular turbines. Energy Storage for use with Distributed Generation-Battery Storage, Capacitor Storage, ultra capacitors and Mechanical Storage: Flywheels, Pumped and Compressed Fluids.

Module 2

Grid Interconnection Options, Pros and Cons of DG – Grid Interconnection, Standards of interconnection. Recent trends in power electronic DG interconnection. General power electronic DG interconnection topologies for various sources and control. Control of DG inverters, current control and DC voltage control for stand alone and grid parallel operations. Protection of the converter, Control of grid interactive power converters, phase locked loops ,synchronization and phase locking techniques, current control, DC bus control during grid faults, converter faults during grid parallel and stand alone operation.

Module 3

Intentional and unintentional islanding of distribution systems. Passive and active detection of unintentional islands, non detection zones. Reactive power support using DG. Power quality improvement using DG, Power quality issues in DG environment.

Economic aspects of DG- Generation cost, investment, tariffs analysis. Hybrid energy systems.

Distributed generation in the Indian scenario – case studies.

References:

1. "Distributed Power Generation, Planning & Evaluation" by H. Lee Willis & Walter G. Scott, 2000 Edition, CRC Press Taylor & Francis Group.
2. "Renewable energy power for a sustainable future" by Godfrey Boyle ,2004 Oxford University Press in association with the Open university.
3. "Fundamentals of renewable energy systems "by D.Mukherjee, S.Chakrabarti, New Age International Publishers.

4. Advanced Power Electronic Interfaces for Distributed Energy Systems Part 1: Systems and Topologies by W. Kramer, S. Chakraborty, B. Kroposki, and H. Thomas, March 2008,*Technical Report* NREL/TP-581-42672

In addition to readings from the textbook, the course will use selected papers and articles from professional magazines and industry internet sources as reference materials.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 2001 TRANSIENT ANALYSIS IN POWER SYSTEM 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective :To introduce various types of transient over voltages in power system and the methods to overcome them

Module 1

Lightning and travelling waves : Transients in electric power systems - internal and external causes of over voltages - lightning strokes - mathematical model to represent lightning - stroke to tower and midspan - travelling waves in transmission lines selection of typical wave to represent over voltages.

Switching Transients : Switching transients - the circuit closing transient - the recovery transient initiated by the removal of the short circuit — double frequency transients

Module 2

Abnormal switching transients - current suppression - capacitance switching - arcing ground - transformer inrush current - ferro resonance - neutral connections - transients in switching a three phase reactor- three phase capacitor.

Surges in transformers: Step voltage - voltage distribution in transformer winding -winding oscillations - Travelling wave solutions - Transformer core under surge conditions.

Module 3

Voltage surges -Transformers - Generators and motors -Transient parameter values for transformers - Reactors - Generators - Transmission lines Protective Devices and Systems : Basic idea about protection - surge diverters - surge absorbers - ground fault neutralizers - protection of lines and stations by shielding -ground wires - counter poises - driven rods - modern lightning arrestors - insulation coordination - protection of alternators- industrial drive systems.

References:

1. Allen Greenwood, *'Electrical transients in power systems'*, Wiley Interscience, 1971
2. Bewely LW, *"Travelling Waves and transmission systems'*, Dover Publications, New York,1963
3. Gallaghar P J and Pearmain A J, *'High Voltage Measurement, Testing and Design* ,John Wiley and sons, New York, 1982.
4. .Klaus Ragallea *"Surges and High voltage networks"* Press, 1980.
5. Diesendrof *W "Over Voltages on High Voltage Systems"*, Rensselaer Book Store, roy, New York, 1971.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 2002 FLEXIBLE AC TRANSMISSION SYSTEM 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: Advances in Power electronics Industry led to rapid development of Power Electronics controllers for fast real and reactive power control The aim of the course is to introduce these advancements

Module 1

Power flow in Power Systems-Benefits of FACTS Transmission line compensation- Uncompensated line -shunt compensation - Series compensation -Phase angle control. Reactive power compensation – shunt and series compensation principles – reactive compensation at transmission and distribution level – Static versus passive VAr Compensators – Converters for Static Compensation

Module 2

Static shunt Compensator - Objectives of shunt compensations, Methods of controllable VAR generation - Variable impedance type VAR Generators -TCR , TSR, TSC, FC-TCR Principle of operation, configuration and control , Switching converter type VAR generators- Principle of operation, configuration and control , SVC and STATCOM , Comparison between SVC and STATCOM- Applications

Module 3

Static Series compensator - Objectives of series compensations , Variable impedance type series compensators - GCSC. TCSC, TSSC - Principle of operation, configuration and control. Application of TCSC for mitigation of SSR. Switching converter type Series Compensators (SSSC)- Principle of operation, configuration and control. Static Voltage and Phase Angle Regulators (TCVR &TCPAR): Objectives of Voltage and Phase angle regulators, Thyristor controlled Voltage And Phase angle Regulators

Unified Power Flow Controller: Circuit Arrangement, Operation and control of UPFC- Basic principle of P and Q control- independent real and reactive power flow control- Applications - Introduction to interline power flow controller. Modeling and simulation of FACTS controllers

References:

1. T J E Miller, *"Reactive Power Control in Power Systems'* , John Wiley, 1982
2. J Arriliga and N R Watson, *"Computer modeling of Electrical Power Systems'*, Wiley, 2001
3. N G Hingorani and L Gyugyi, *'Understanding FACTS'*, IEEE Press, 2000
4. K R Padiyar, “FACTS Controllers in Power Transmission and Distribution”, New Age International Publishers, 2007
5. Y.H. Song and A.T. Johns, *'Flexible ac Transmission Systems (FACTS)* IEE Press, 1999
6. Ned Mohan et.al *''Power Electronics*' John Wiley and Sons.
7. *Dr Ashok S & KS Suresh kumar, 'FACTS Controllers and applications "* course book for STTP 2003
8. Current Literature

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 2004 SOFT COMPUTING APPLICATION TO POWER SYSTEM 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: The course provides exposure to soft computing techniques and its applications in Power Systems

Module 1

Biological foundations - ANN models - Types of activation function - Introduction to Network architectures -Multi Layer Feed Forward Network (MLFFN) - Radial Basis Function Network (RBFN) - Recurring Neural Network (RNN). Supervised and unsupervised learning - Error-correction learning - Hebbian learning – Boltzmen learning - Single layer and multilayer perceptrons - Least mean square algorithm – Back propagation algorithm – application in power systems-load flow analysis-contingency analysis-power quality analysis

Module 2

Fuzzy set operations - Properties - Membership functions - Fuzzy to crisp conversion - fuzzification and defuzzification methods -fuzzy control systems –fuzzy logic model s-applications in power systems-AGC single area system-small signal stability

Module 3

Genetic Algorithm -Introduction - basic concepts –application
Adaptive fuzzy systems - hybrid systems - Adaptive Neuro fuzzy Inference System (ANF1S) controllers

References

1. J.M. Zurada. *Introduction to artificial neural systems,* Jaico Publishers, 1992.
2. Simon Haykins. *Neural Networks - A comprehensive foundation,* Macmillan College, Proc, Con, Inc, New York. 1994.
3. D. Driankov. H. Hellendorn, M. Reinfrank, *Fuzzy Control - An Introduction,* Narora Publishing House, New Delhi, 1993.
4. HJ. Zimmermann, *Fuzzy set theory and its applications,* 111 Edition, Kluwer Academic Publishers, London.
5. G.J. Klir, Boyuan, *Fuzzy sets and fuzzy logic,* Prentice Hall of India (P) Ltd, 1997.
6. Stamatios V Kartalopoulos, *Understanding neural networks and fuzzy logic basic concepts and applications,* Prentice Hall of India (P) Ltd, New Delhi, 2000.
7. Timothy J. Ross, *Fuzzy logic with engineering applications,* McGraw Hill, New York.
8. Suran Goonatilake, Sukhdev Khebbal (Eds,), *Intelligent hybrid systems,* John Wiley & Sons, New York, 1995.
9. Vose Michael D., *Simple Genetic Algorithm - Foundations And Theory,* Prentice Hall of India.
10. Rajasekaran & Pai, *Neural Networks, Fuzzy Logic, and Genetic Algorithms: Synthesis and Applications,* Prentice-Hall of India, 2007.
11. J.S.Roger Jang, C.T.Sun and E.Mizutani, NEURO FUZZY AND SOFT COMPUTING, prentice hall inc., New Jersey, 1997.
12. Recent Journals

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EME 2002 PWM CONVERTERS AND APPLICATIONS 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks	

Course Objective : To equip the students with knowledge of PWM technique that has emerged from recent research and various topologies of multi-level converters and application of PWM converters

Module 1

Use of Single-Pole-Double-Throw Single-Pole-Multi-Throw switches to describe Converter Topologies: Basic switch constraints-Implementation of various switch schemes using available power semiconductor devices.

Topologies of Inverters and Rectifiers--relation between Pole voltages, Line voltages and Line-to-load neutral voltages in multi-phase two-level inverters-Basic modulation methods--duty ratio--sine-triangle modulation--implementation of unipolar and bipolar modulation--three-phase inverters- Harmonic performance of Unipolar and Bipolar modulation schemes in single phase and three phase inverters-linear modulation and over modulation

Module 2

Space vector PWM - conventional sequence- 30 degree and 60 degree bus clamped PWM--relation between sine-triangle and space vector PWM--dc bus utilisation of SPWM and SVPWM. Over modulation in SVPWM-Over modulation zones.

Synchronised and non-synchronised PWM-Multilevel Converters: Topologies. Neutral Point Clamped and Flying Capacitor Topologies. Cascaded Multilevel Inverters. Multilevel Converters Modulation -- Carrier based approach-Conventional Space Vector Modulation for 3-level inverters.

Module 3

Applications of PWM converters--Active front end rectifier--vector control of front-end rectifier-Control of Shunt active filter-

PWM converters in AC drives-Current Control in inverters: Current controlled PWM VSI -Hysteresis Control - fixed band and variable band hysteresis.

Selective Harmonic Elimination-Derivation of simultaneous transcendental equations for elimination of harmonics-PWM Current Source Inverters--Current Space Vectors- Space Vector Modulation of CSI--Application of CSI in high-power drives-Fundamental principles of Hybrid schemes with CSI and VSI.

References:

Books:

1. Joseph Vithayathil, “Power Electronics”, McGraw-Hill
2. Bin Wu, “High Power Converters and AC Drives,”
3. Ned Mohan, *et. al.,* “Power Electronics: Converters, Design and Applications,” Wiley
4. L. Umanand, “Power Electronics: Essentials and Applications,” Wiley, 2009.
5. Werner Leonhard, “Control of Electrical Drives,”, 3rd Ed., Springer
6. Bimal K. Bose, “Modern Power Electronics and AC Drives,” Prentice Hall

Technical Papers:

1. J.Holtz, “Pulse width modulation - a survey”, IEEE Trans. IE, Vol. IE-39(5), 1992, pp.
2. J.Holtz, “Pulse width modulation for electronic power conversion”, Proc. IEEE, Vol. 82(8), 1994, pp. 1194-1214.
3. V.T.Ranganathan, “Space vector modulation - a status review”, Sadhana, Vol. 22(6), 1997, pp. 675-688.
4. L.M.Tolbert, F.Z.Peng and T.G.Habelter, “Multilevel inverters for large electric drives, IEEE Transactions on Industry Applications, Vol.35, No.1, pp. 36-44, Jan./Feb. 1999.

5. Sangshin Kwak, Hamid A. Toliyat, “A Hybrid Solution for Load-Commutated-Inverter- Fed Induction Motor Drives,” IEEE Trans. on Industry Applications, vol. 41, no. 1, January/February 2005.
6. Sangshin Kwak, Hamid A. Toliyat, “A Hybrid Converter System for High-Performance Large Induction Motor Drives,” IEEE Trans. on Energy Conversion, vol. 20, no. 3, September 2005.
7. Sangshin Kwak, Hamid A. Toliyat, “A Current Source Inverter With Advanced External Circuit and Control Method,” IEEE Trans. on Industry Applications, vol. 42, no. 6, November/December 2006.
8. A.R. Beig, and V.T. Ranganathan, “A novel CSI-fed Induction Motor Drive,” IEEE Trans. on Power Electronics, vol. 21, no. 4, July 2006.
9. H.Stemmler, “High-power industrial drives,” Proc. IEEE, Vol. 82(8), 1994, pp. 1266- 1286.

Thesis/Reports:

1. A.R.Beig, “Application of three level voltage source inverters to voltage fed and current fed high power induction motor drives” -Ph.D. Thesis of Electrical Engineering, IISc, Bangalore,April 2004.
2. G. Narayanan, “Synchronised Pulsewidth Modulation Strategies based on Space Vector Approach for Induction Motor Drives”-Ph.D. Thesis of Electrical Engineering, IISc, Bangalore,August 1999.
3. Debmalya Banerjee, “Load Commutated Current Source Inverter fed Induction Motor drive with sinusoidal voltage and current,” - PhD. Thesis of Electrical Engineering, IISc, Bangalore, June 2008.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPC 2001 DIGITAL PROTECTION OF POWER SYSTEM 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective*:* To get an overall idea of different types of static relays and its applications, and about the modern techniques used in power system protection

Module 1

General philosophy of protection- Qualities of relaying - Definitions - Characteristic Functions; Classification – analog-digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection.

Module 2

Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms-travelling wave protection schemes

Module 3

Protection of power system apparatus –protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection. Bus bar protection, line protection, distance protection–long EHV line protection, Power line carrier protection.

References:

1. A T John and A K Salman- Digital protection for power systems-IEE power series-15, Peter Peregrines Ltd,UK,1997
2. C. Russeil. Mason, The art and science of protective relaying, John Wiley &sons, 2002
3. Donald Reimert, ,Protective relaying for power generation systems, Taylor & Francis-CRC press 2006
4. Gerhard Ziegler-Numerical distance protection, Siemens, 2nd ed, 2006
5. A.R.Warrington, Protective Relays, Vol .1&2, Chapman and Hall, 1973
6. T S.Madhav Rao, Power system protection static relays with microprocessor applications, Tata McGraw Hill Publication, 1994
7. Power System Protection Vol. I, II , III&IV, The Institution Of Electrical Engineers, Electricity Association Services Ltd., 1995
8. Helmut Ungrad , Wilibald Winkler, Andrzej Wiszniewski, Protection techniques in electrical energy systems, Marcel Dekker, Inc. 1995
9. Badri Ram , D.N. Vishwakarma, Power system protection and switch gear, Tata McGraw Hill, 2001

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

ECC1002 DIGITAL CONTROL SYSTEMS 3-0-0-3

Structure of the course

Lecture : 3Hrs/Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 marks

Course Objectives

1. To introduce the concepts of digital control.
2. To analyse the stability using different methods.
3. To design compensators using classical methods.
4. To impart in-depth knowledge in state space design of digital controllers and observers.
5. To analyse the system performance with controller and estimator in closed loop.

Learning Outcomes

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

1. To analyse a given discrete-time system and assess its performance.
2. To design a suitable digital controller for a given system to meet the specifications.
3. To design a digital controller and observer for a given system and evaluate its performance.

Module I

Analysis in Z-domain: Review of Z Transforms, Pulse Transfer Function and sample and hold, effect of damping, mapping between the s plane and the z plane, stability analysis of closed loop systems in the z- plane, Jury's test, Schur Cohn test, Bilinear Transformation, Routh-Hurwitz method in w-plane. Discrete equivalents: Discrete equivalents via numerical integration-pole-zero matching-hold equivalents.

Module II

Digital Controller Design for SISO systems: Design based on root locus method in the z-plane, design based on frequency response method design of lag compensator, lead compensator , lag lead compensator, design of PID Controller based on frequency response method- Direct Design-method of Ragazzini. Design using State Space approach, pulse transfer function matrix, discretization of continuous time state space equations, Controllability, Observability, Control Law Design, decoupling by state variable feedback, effect of sampling period.

Module III

Estimator/Observer Design: Full order observers - reduced order observers, Regulator Design, Separation Principle -case with reference input. MIMO systems: Introduction to MIMO systems, Design Concept - Case Studies.

References

1. Gene F. Franklin, J. David Powell, Michael Workman, "Digital Control of Dynamic Systems", Pearson, Asia.
2. J. R. Liegh, "Applied Digital Control", Rinchart & Winston lnc., New Delhi.
3. Frank L. Lewis, "Applied Optimal Control & Estimation", Prentice-Hall, Englewood Cliffs NJ, 1992.
4. Benjamin C Kuo, "Digital Control Systems", 2nd Edition, Saunders College publishing, Philadelphia, 1992.
5. K. Ogata, "Discrete-Time Control Systems", Pearson Education, Asia.
6. C. L. Philips, H T Nagle, "Digital Control Systems", Prentice-Hall, Englewood Cliffs, New Jersey, 1995.
7. R. G. Jacquot, "Modern Digital Control Systems", Marcel Decker, New York, 1995.
8. M. Gopal, "Digital control and state variable methods", Tata Mc Graw Hill, 1997.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

ECC2001 OPTIMAL CONTROL THEORY 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course objectives

1. To design suitable performance measure to meet the specification requirements.
2. To analyse the physical system and design the controller by optimizing the suitable performance criteria by satisfying the constraints over the state and inputs.
3. To apply the design algorithms to various physical systems.
4. Provides a solid foundation on functions, functionals, various norms, etc.

Learning Outcomes

4. Formulate the optimal controller design problem.
5. Apply constrained optimization to various physical systems.
6. Implement optimal control algorithms to track the response of the system through a predefined trajectory

Module I

Optimal control problems- mathematical models-selection of performance measures, constraints- classification of problem constraints-problem formulation-examples.
Dynamic Programming- Optimal control law-principle of optimality - Application to decision making-routing problem-Hamilton Jacobi Bellman equation- Standard Regulator Problem: Solution of finite time regulator Problem – Discrete Linear Regulator Problem – Infinite time Regulator Problem – Stability.

Module II

Calculus of Variations: basic concepts - variation of a functional - extremals – fundamental theorem in calculus of variation - Euler equation - Piecewise smooth extremals – constrained extrema – Hamiltonian - necessary condition for optimal control.

Module III

Pontryagin's Minimum Principle: Minimum time problem, Minimum Control Effort problem, Minimum Fuel problem, Minimum Energy problem, Singular intervals, Effects of Singular Intervals, Numerical Examples.

References

1. Donald E Kirk, "Optimal Control Theory- An introduction", Prentice-Hall Inc. Englewood Cliffs, New Jersey, 1970.
2. Brian D O Anderson, John B Moore, "Optimal Control-Linear Quadratic methods", Prentice-Hall Inc, New Delhi, 1991.
3. Athans M and P L Falb, "Optimal control- An Introduction to the Theory and its Applications", McGraw Hill Inc, New York, 1966.
5. Sage A P, "Optimum Systems Control", Prentice-Hall Inc, Englewood Cliffs, New Jersey, 1968.
6. D. S. Naidu, "Optimal Control Systems", CRC Press Newyork Washington D. C. , 2003.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

ECC2002 NONLINEAR CONTROL SYSTEMS 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course objectives

1. To study the essentials of Non-linear control.
2. To extend the analysis techniques for classical control theory to nonlinear system.
3. To analyse the physical s ystem with inherent non-linearity for stability and performance.
4. To provide the necessary methods for designing controllers for Non-linear systems.

Learning Outcomes

1. The student will gain insight into the complexity of nonlinear systems.
2. The student will be able to apply methods of characterizing and understanding the behavior of systems that can be described by nonlinear ordinary differential equations.
3. The student will be able to use tools including graphical and analytical for analysis of nonlinear control systems.
4. The student will be able to use a complete treatment of design concepts for linearization via feedback.
5. The student will demonstrate an ability to interact and communicate effectively with peers.

Module I

Describing function analysis: Fundamentals-Describing Function of saturation, dead-zone, on-off non-linearity, backlash, Hysteresis-Describing Function Analysis of Non-linear Systems, Dual Input Describing Function (DIDF)-Existence of Limit Cycles.
Phase plane analysis: Concept of Phase Portraits-Singular Points Characterization - Analysis of Non-linear Systems Using Phase Plane Technique – Classification of Equilibrium Points -Stable & Unstable – Limit Cycle Analysis- Existence – Stability.

Module II

Concept of stability: Definition of Stability - Stability in the Sense of Lyapunov, Analysis of Instability, Absolute Stability, Zero- Input and BIBO Stability, Second method of Lyapunov- Stability theory for Continuous and Discrete Time Systems - Aizermanns and Kalman's conjecture - Construction of Lyapunov function for non linear systems - Methods of Aizerman-Zubov - Variable Gradient Method.
Absolute Stability:- Lure’s Problem - Kalman- Yakubovich-Popov Lemma - Circle Criterion Popov's stability Criterion - Popov's Hyper Stability Theorem.

Module III

Non-linear control system design: Design via Linearization – Stabilization – Regulation via Integral Control – Gain Scheduling Feedback Linearization – Stabilization – tracking – Regulation via Integral Control - Cascade Designs-Back Stepping Design.

References

1. Hassan K Khalil, “Nonlinear Systems”, Macmillan Publishing Company, NJ, 2004.
2. John E Gibson, “Nonlinear Automatic Control”, Mc Graw Hill, NewYork.
3. Jean-Jacques E. Slotine and Weiping Li, “Applied Nonlinear Control”, Prentice-Hall, NJ, 1991.
4. M Vidyasagar, “Nonlinear Systems Analysis”, Prentice-Hall, India, 1991,
5. Shankar Sastry, “Nonlinear System Analysis, Stability and Control”, Springer, 1999.
6. Alberto Isidori, “Nonlinear control systems: an introduction”, Springer-Verlag, 1985.

Structure of the question paper

For the end semester examination the question paper consists of at least 60% design problems and derivations. The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAD 2001 DEREGULATION IN POWER SYSTEMS 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: Objective of the course is to introduce the deregulation in the power industry.

Module 1

The Electric Industry and Its Traditional Regulated Structure: Electric Utility Functions and Systems - Electric Utility Resources and Organization -Vertical Integration and Monopoly Regulation - Electric Utility Business Frameworks - Government Regulatory Agencies and Commissions

The Electric Industry Under De-Regulation – An Overview: De-Regulation: Concepts and Evolution, Competition at the Wholesale Generation Level, Independently Operated Regional Transmission Grids, - The Electric Utility Industry Under De-Regulation

History of the Electric Power Industry: Growth of Electrical Usage - The Growth of Electrical Systems Technology - The Rise of the Electrical Utility Industry

Module 2

Distributed Generation and Storage: Distributed Power Generation - Types of Distributed Generators - Distributed Power Storage

Regulation and De-Regulation: Why Were Electric Utilities Regulated? Why De-Regulate? The Good and Bad of Utility Regulation -Goals for and Effects of De-Regulation - Comparing Four Approaches to Regulation and De-Regulation - Increased Services From and Financial Pressures On LDCs

De-Regulation at the Wholesale Power Level: The Wholesale Power Marketplace – bidding of electricity - Buying Energy vs. Buying Capacity - Wholesale Power Pricing

Module 3

The Power Grid in the De-Regulated Industry: Generation and Transmission in a De-Regulated Industry - The Wholesale Transmission Level - Transmission Service Pricing- Location Based Pricing.

Power Distribution in a De-Regulated Industry: Open Access Distribution - Changes in Distribution Operations - Will Distribution Performance Improve Due to “Competition”?

Retail Sales in a Fully De-Regulated Industry: Load Aggregation and Services - RESCO Identities and Industry Position.

Deregulation Scenario in India – Indian Electricity Act 2003

References:

1) Understanding Electric Utilities and De-Regulation, 2nd Edition, Lorrin Philipson H. Lee Willis. CRC Press

2) Current Literature

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPC 1003 POWER QUALITY 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: *Objective of the course is to discuss various power quality issues and different methods to control them*

Syllabus

Module 1

Understanding Power quality -Power quality issues in distribution systems - Sources and Effects of power quality problems, Power quality monitoring : Need for power quality monitoring, types of power quality disturbances - Voltage sag (or dip) ,Transients, short duration voltage variation, Long duration voltage variation, voltage imbalance, waveform distortion, and voltage flicker- methods of characterization- Power Quality Costs Evaluation - Causes and effects of power quality disturbances.

Module 2

Harmonics -mechanism of harmonic generation-harmonic indices (THD, TIF, DIN, C - message weights). standards and recommended practices - Harmonic sources - SMPS, Three phase power converters, arcing devices, saturable devices, fluorescent lamps- Harmonic Analysis - Fourier series and coefficients, the fourier transforms, discrete fourier transform, fast fourier transform, Window function- Effects of Power System harmonics on Power System equipment and loads

Module 3

Harmonic elimination - Design philosophy of filters to reduce harmonic distortion - Power conditioners ,passive filter, active filter - shunt , series, hybrid filters, Computation of harmonic flows- Voltage regulation-devices for voltage regulation-capacitors for voltage regulation. Dynamic Voltage Restorers for sag, swell and flicker problems

Electromagnetic Interference (EMI -introduction -Frequency Classification - Electrical fields - Magnetic Fields - EMI Terminology - Power frequency fields - High frequency Interference - EMI susceptibility - EMI mitigation -Cable shielding- Health concerns of EMI

References:4

1. R.C.Durgan, MF Me Granaghen, H W Beaty, *'Electrical Power System Quality'*, McGraw hill
2. Jose Arillaga, Neville R Watson, *'Power System Harmonics'*, Wiley, 1997
3. C.Sankaran, *'Power Quality'*, CRC Press2002
4. G T Heydt, *'Power Quality'*, stars in circle publication Indiana 1991
5. Math H Bollen, *''Understanding Power Quality Problems'*
6. *Power Quality hand Book*
7. *J.B.Dixit & Amit Yadav ; Electrical Power Quality*
8. Recent literature

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPD 2001 NEW AND RENEWABLE SOURCES OF ENERGY 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective*:* This subject provides sufficient knowledge about the promising new and renewable sources of energy so as to equip students capable of working with projects related to it aim to take up research work in connected areas

Module 1

Direct solar energy-The sun as a perennial source of energy; flow of energy in the universe and the cycle of matter in the human ecosystem; direct solar energy utilization; solar thermal applications - water heating systems, space heating and cooling of buildings, solar cooking, solar ponds, solar green houses,solar thermal electric systems; solar photovoltaic power generation; solar production of hydrogen.

Module 2

Energy from oceans-Wave energy generation - potential and kinetic energy from waves; wave energy conversion devices; advantages and disadvantages of wave energy- Tidal energy - basic principles; tidal power generation systems; estimation of energy and power; advantages and limitations of tidal power generation- Ocean thermal energy conversion (OTEC); methods of ocean thermal electric power generation Wind energy - basic principles of wind energy conversion; design of windmills; wind data and energy estimation; site selection considerations.

Module 3

Classification of small hydro power (SHP) stations; description of basic civil works design considerations; turbines and generators for SHP; advantages and limitations. Biomass and bio-fuels; energy plantation; biogas generation; types of biogas plants; applications
of biogas; energy from wastes
Geothermal energy- Origin and nature of geothermal energy; classification of geothermal resources; schematic of geothermal power plants; operational and environmental problems
New energy sources (only brief treatment expected)-Fuel cell: hydrogen energy; alcohol energy; nuclear fusion: cold fusion; power from satellite stations

References

1. John W Twidell and Anthony D Weir, *'Renewable energy resources'* , English Language Book Society (ELBS), 1996
2. Edited by Godfrey Boyle *'Renewable energy -power for sustainable future* ,Oxford University Press in association with the Open University, 1996
3. S A Abbasi and Naseema Abbasi, *'Renewable energy sources and their environmental impact"* Prentice-Hall of India, 2001
4. G D Rai, *'Non-conventional sources of energy'*, Khanna Publishers, 2000
5. G D Rai, *'Solar energy utilization*', Khanna Publishers, 2000
6. S L Sah, *'Renewable and novel energy sources'*, M.I. Publications, 1995
7. *S Rao and B B Parulekar, 'Energy Technology[9], Khanna Publishers, 1999*

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPD 2002 SCADA SYSTEMS AND APPLICATIONS 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: Objective of the course is to introduce SCADA systems, its components, architecture, communication and applications.

Module 1

Introduction to SCADA Data acquisition systems- Evolution of SCADA, Communication technologies-. Monitoring and supervisory functions- SCADA applications in Utility Automation, Industries- SCADA System Components: Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED),Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems

Module 2

SCADA Architecture: Various SCADA architectures, advantages and disadvantages of each system - single unified standard architecture -IEC 61850-SCADA Communication:Various industrial communication technologies -wired and wireless methods and fiber optics-Open standard communication protocols

Module3

SCADA Applications: Utility applications- Transmission and Distribution sector -operations, monitoring, analysis and improvement. Industries - oil, gas and water. Case studies, Implementation. Simulation Exercises

References:

1. Stuart A Boyer. SCADA-Supervisoiy Control and Data Acquisition', Instrument Society of America Publications. USA. 1999.
2. Gordan Clarke, Deon RzynAzvs,Practical Modern SCADA Protocols: DNP3, 60870J and Related Systems', Newnes Publications, Oxford, UK,2004

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

SEMESTER III

EAE3001 POWER SYSTEM MANAGEMENT **3-0-0-3**

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: *Objectives of the course is to introduce various operational and management issues in power system*

Module 1

Deregulation: Introduction - Deregulation of Electric Utilities - Energy Generation under new environment - Competitive whole sale electricity market - Transmission expansion in new environment —Transmission Open Access - Pricing Electricity in Deregulated environment- Availability based Tariff

Advances in online control of Power System - Application of Internet and GPS in power system control

Module 2

Load characteristics and load forecast: Basic definitions- load definitions, load factor definitions, diversity principle in distribution systems, Load Forecast- factors affecting load forecasting methods, small areas load forecasting, spatial load forecasting methods, simulation, trending and mixed load forecasting methods

Basics of Power System Economics & Short-term Operation Planning of Power System, Load curves and load duration curves, Economic load dispatch- concept of marginal cost and Kuhn-Tucker's condition of optimum in power dispatch, participation factors

Module 3

Electrical Safety: Hazards of electricity - Electrical Safety Equipment - Safety Procedures and methods - Grounding of Electrical Systems and Equipment - Regulatory and Legal Safety Requirements and Standards - Safety Audits - Rescue and first aid procedures.

Energy Management: Energy Conservation Through Demand Side Management-Load Management- Reactive Power Control.

Blackouts and cascading failures: Blackout mechanism, modeling of blackouts and cascading failures, prediction of blackouts, control of blackouts – Case studies: July 12 India Blackout, August 14, 2003 blackout in North America power grid

References:

1. Loi Lei Lai. 'Power System Restructuring and Deregulation: Trading Performance and Information Technology" John Wiley, 2001
2. 'Proceedings of lEEE February 2000
3. Steven Stoft, 'Power System Economies', IEEE Press, 2002
4. John Cadick, Mary Capelli - Schellpfeffer, Dennis. K, 'Electrical Safety Handbook", Me Graw Hill, 2005.
5. David. J. Mame, cMc-Graw Hills' National Electrical Safety Code (NESC) Handbook', Me Graw Hill, 2002
6. Craig B Smith, 'Energy management principles*, Pergamon Press
7. K. Bhattacharya, M. H. J. Bollen and J. E. Daalder, Operation of restructured power systems, Kluwer Academic Publishers, USA, 2001.
8. Technical analysis of Aug. 14, 2003 blackout, Report of the NERC Steering Group, 2004 (www.nerc.com)
9. Current Literature

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAE3002 CAPTIVE POWER SYSTEMS 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: *Objectives of the course is to introduce captive power systems and energy storage systems in power system*

Module -1

Captive Power Plants: Selection Considerations - Diesel Generator Captive Power Plants – Comparison of different types of captive power plants - Selection and Installation Factors - Sizing of a Genset: High Speed Engine or Slow/Medium Speed Engine, Capacity Combinations, Air Cooling Vs. Water Cooling, get over-heated during summer months - Safety Features - Parallel Operation with Grid- Maximum Single Load on DG Set - Unbalanced Load Effects - Neutral Earthing - Site Condition Effects on Performance Derating - Operational Factors - Load Pattern & DG Set Capacity - Sequencing of Loads - Load Pattern - Load Characteristics - Power Factor - Unbalanced Load Transient Loading

Module -2

Classification of EES systems -Roles of electrical energy storage (EES) system – Emerging needs for EES - Types and features of energy storage systems Mechanical storage systems - Pumped hydro storage (PHS) - Compressed air energy storage (CAES) - Flywheel energy storage (FES) - Electrochemical storage systems: Secondary batteries - Flow batteries - Chemical energy storage: Hydrogen (H2) - Synthetic natural gas (SNG) - Electrical storage systems: Double-layer capacitors (DLC) -Superconducting magnetic energy storage (SMES)- Thermal storage systems - Standards for EES - Technical comparison of EES technologies

Module -3

Combined Cycle Power Plant: Introduction - Typical cycles - Gas Turbine - G as Turbine HRSG Systems - Steam Turbine -Combined Cycle Plants -Availability and reliability

SMPS- Characteristics – Steady state Analysis - Control methods:-Design of feedback compensation.
UPS: Necessity - types - typical layouts of UPS. Stand alone high quality Electronics Power Supplies

References:

1. Bueuru of Energy Efficiency, Study material for Energy manager programme, 2012
2. Irving M.Gottilieb "Power supplies, Switching Regulators, Inverters and Converters" BPB Publications – 1985
3. RK Chetty "Switched Power Supply Design" BPB Publication- 1987
4. Current Literature

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAE3003 SMART GRID TECHNOLOGIES & APPLICATIONS 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: 1. Develop a conceptual basis for Smart Grid
2. Equip the Students with a thorough understanding of various communication technologies and management issues with smart grid.

Learning outcome: A clear understanding of smart grid technology to enable students to pursue research in that area.

Module -1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of SmartGrid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient & Self-Healing Grid, Present development & International policies in Smart Grid. Case study of Smart Grid . CDM opportunities in Smart Grid.
Smart Grid Technologies: Introduction to Smart Meters, Real Time Pricing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers. Smart Substations, Substation Automation, Feeder Automation. Geographic Information System (GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

Module -2

Micro grids and Distributed Energy Resources: Concept of micro grid, need & applications of micro grid, formation of micro grid, Issues of interconnection, protection & control of micro grid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuel cells, micro turbines, Captive power plants, Integration of renewable energy sources.

Module -3

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.
Information and Communication Technology for Smart Grid: Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighbourhood Area Network (NAN), Wide Area Network (WAN). Bluetooth, Zig-Bee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Basics of CLOUD Computing & Cyber Security for Smart Grid. Broadband over Power line (BPL). IP based protocols.

References:

1.Ali Keyhani, Mohammad N. Marwali, Min Dai “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley
2.Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press
3. JanakaEkanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama,“ Smart Grid: Technology and Applications”, Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, “Smart Grids”, Wiley Blackwell
5. Tony Flick and Justin Morehouse, “Securing the Smart Grid”, Elsevier Inc. (ISBN: 978-1-59749-570-7)
6. Peter S. Fox-Penner, “Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities”

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAE3004 CONTROL OF INDUSTRIAL DRIVES 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: *This course introduces various control of dc drives, scalar and vector control of induction motor drives, control of synchronous motor drives, and control of brush less dc and ac motor drives*

Module -1

Separately Excited DC Motors and DC series motors*:* system model-braking-speed control-motor dynamics *DC Drives*-fully controlled rectifier drives-inverter operation-half-controlled rectifier drives-single quadrant-two quadrant and four quadrant drives-power in load and source circuits-closed loop control of DC drives-transfer function-micro computer control of DC drives-block diagram and flowchart

Module -2

Three Phase Induction Motors -equivalent circuit-braking-speed control-variable voltage operation-variable frequency operation(review)-constant volts/Hz operation-Voltage source inverter drives-Pulse Width Modulated inverter drives-space vector PWM drives-CSI drives-slip power recovery drives-Vector control-DC drive analogy-direct vector control-indirect vector control-Direct Torque Control (DTC)

Module -3

Synchronous Motor Drives -Volt/hertz control of synchronous motor-closed loop operation-self-controlled synchronous motors Switched Reluctance Motor Drives. Permanent Magnet Brushless DC motor Drives, Sensor less Speed Control of DC and AC Drives.

References:

1. Bimal K Bose, *'Modern Power Electronics and AC Drives"* , Pearson Education Asia, 2003
2. Peter Vas, *"Sensorless Vector and Direct Control'* , Oxford London, 1998
3. Dubey G K. *'Power Semiconductor Controlled Drives'* , Prentice-Hall, New Jersey, 1989
4. Peter Vas, *'"Sensorless Vector and Direct Control'* , Oxford London, 1998
5. Muhammad H Rashid, *'Power Electronic Circuits, Devices and Applications'* , Pearson Edn Asia, 2003
6. NK De,PK Sen, 'Electrical Drives' , Prentice-Hall of India, 2002
7. Dewan S B, G R Slemons, A Straughan, 'Power Semiconductor Drives' , John Wiley and Sons, 1984

8 Jay P Agarwal, *'Power Electronic Systems Theory and Design'* , Prentice Hall, New Jersey, 2001

9 J M D Murphy,[c] *Thyristor Control of AC Drives'*, Papermon Press, 1973

10 T J.E Miller,' *Brushless PM and Reluctance Motor Drives'* ,C.Larendon Press, Oxford

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAE3005 VOLTAGE STABILITY IN POWER SYSTEMS 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: Introduce the analysis of voltage stability in power systems

Module -1

Introduction to Voltage Stability: Definitions: Voltage Stability, Voltage Collapse, Voltage Security; Physical relation indicating dependency of voltage on reactive power flow; Factors affecting Voltage collapse and instability; Previous cases of voltage collapse incidences.

Graphical Analysis of Voltage Stability: Comparison of Voltage and angular stability of the system; Graphical Methods describing voltage collapse phenomenon: P-V and Q-V curves; detailed description of voltage collapse phenomenon with the help of Q-V curves.

Module -2

Analysis of Voltage Stability: Analysis of voltage stability on SMLB system: Analytical treatment and analysis.

Voltage Stability Indices: Voltage collapse proximity indicator; Determinant of Jacobin as proximity indicators; Voltage stability margin.

Module -3

Power System Loads: Loads that influences voltage stability: Discharge lights, Induction Motor, Air-conditioning, heat pumps, electronic power supplies, OH lines and cables.

Reactive Power Compensation: Generation and Absorption of reactive power; Series and Shunt compensation; Synchronous condensers, SVCs; OLTCs; Booster Transformers.

Voltage Stability Margin Stability Margin: Compensated and un-compensated systems.

Voltage Security: Definition; Voltage security; Methods to improve voltage stability and its practical aspects.

References:

1) “Power System Voltage Stability”- C.W.TAYLOR, Mc Graw Hill, 1994.

2) “Performance, operation and control of EHV power transmission system”- A.CHAKRABARTHY, D.P. KOTARI and A.K.MUKOPADYAY, A.H.Wheeler Publishing, I Edition, 1995.

3) “Power System Dynamics: Stability and Control” – K.R.PADIYAR, II Edition, B.S.Publications

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EAE3006 ADVANCED DIGITAL SIGNAL PROCESSING 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: To introduce the signal processing fundamentals, design of filter and various issues with digital signal processing

Module -1

Discrete time signals, systems and their representations: Discrete time signals- Linear shift invariant systems- Stability and causality- Sampling of continuous time signals- Discrete time Fourier transform- Discrete Fourier series- Discrete Fourier transform- Z- transform- Properties of different transforms- Linear convolution using DFT- Computation of DFT

Module -2

Digital filter design and realization structures: Design of IIR digital filters from analog filters- Impulse invariance method and Bilinear transformation method- FIR filter design using window functions- Comparison of IIR and FIR digital filters- Basic IIR and FIR filter realization structures- Signal flow graph representations

Module -3

Analysis of finite word-length effects

Quantization process and errors- Coefficient quantisation effects in IIR and FIR filters- A/D conversion noise- Arithmetic round-off errors- Dynamic range scaling- Overflow oscillations and zero input limit cycles in IIR filters

Statistical signal processing

Linear Signal Models . All pole, All zero and Pole-zero models .Power spectrum estimation- Spectral analysis of deterministic signals . Estimation of power spectrum of stationary random signals-Optimum linear filters- Optimum signal estimation-Mean square error estimation-Optimum FIR and IIR filters.

References:

1. Sanjit K Mitra, Digital Signal Processing: A computer-based approach ,Tata Mc Grow-Hill edition .1998
2. Dimitris G .Manolakis, Vinay K. Ingle and Stephen M. Kogon, Statistical and Adaptive Signal Processing, Mc Grow Hill international editions .-2000
3. Alan V . Oppenheim, Ronald W. Schafer, Discrete-Time Signal Processing, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997
4. John G. Proakis, and Dimitris G. Manolakis, Digital Signal Processing(third edition), Prentice-Hall of India Pvt. Ltd, New Delhi, 1997
5. Emmanuel C. Ifeachor, Barrie W. Jervis , Digital Signal Processing-A practical Approach, Addison . Wesley,1993
6. Abraham Peled and Bede Liu, Digital Signal Processing, John Wiley and Sons, 1976
7. Oppenheim and Schaffer, ‘Discrete time Signal processing’, PHI, 1999.

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 3001 DISTRIBUTION SYSTEM PLANNING AND AUTOMATION 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: Objective of the course is to introduce various advancements in the distribution systems

Module 1

Power System: General Concepts - Distribution of power - Management - systems study - Loads and Energy Forecasting: Power loads - Area Preliminary survey load forecasting - Regression analysis - Correlation analysis - Analysis of time series - Factors in power system loading -Technological forecasting— Sources of error

Planning, Design and Operation methodology: System calculations, Network elements - Distribution load flow: Radial systems, distribution systems with loops - fault studies - effect of abnormal loads, Voltage control - line circuits - harmonics- urban distribution - load variations

Distribution system expansion planning – load characteristics – load forecasting – design concepts – optimal location of sub station – design of radial lines – solution technique.

Module 2

Optimization of distribution systems: Introduction, Costing of Schemes, Typical network configurations - Long and Short term planning, network cost modelling, voltage levels - Synthesis of optimum line networks - Application of linear programming to network synthesis -Optimum Phase sequence – Economic loading of distribution transformers- Worst case loading of distribution transformers

Distribution automation: Distribution automation - Definitions - Project Planning - Communication, Sensors, Supervisory Control and Data Acquisition (SCADA), Consumer Information systems (CIS), Geographical Information Systems (GIS)

Power System reliability: Basic Reliability Concepts and Series, Parallel, Series-Parallel Systems- Development of State Transition Model to Determine the Steady State Probabilities

Module 3

Consumer Services: Supply industry - Natural monopoly - Regulations - Standards - Consumer load requirements — Cost of Supply - load management - theft of power ~ Energy metering - Tariffs: Costing and Pricing, Classification of Tariffs – Deregulated Systems: Reconfiguring Power systems- Unbundling of Electric Utilities- Competition and Direct access

Voltage control – Application of shunt capacitance for loss reduction – Harmonics in the system – static VAR systems –loss reduction and voltage improvement.

References:

1. A.S.Pabla, '*Electrical Power Distribution Systems*', 4th Edn, TMH, 1997
2. Turan Gonen, *'Electrical Power Distribution Engineering'*, McGraw Hill, 1986
3. Colin Bayliss, *'Transmission and Distribution Electrical Engineering'*, Butterworth Heinemann, 1996
4. Pansini: Electrical Distribution Engineering
5. E. Lakervi & E J Holmes .Electricity distribution network design., 2nd Edition Peter Peregrimus Ltd.
6. *Dhillan, B.S., 'Power System Reliability, Safety and Management', An Arbor Sam, 1981*

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 3002 POWER SYSTEM STABILITY AND RELIABILITY 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: To equip the engineers for operating power systems more effectively and reliably utilizing the resources in an optimal manner

Module 1

Concept of Power system stability-Types of stability-Transient stability analysis: An Elementary View of Transient Stability-Structure of a complete power system model for transient stability analysis-Transient Stability Enhancement

Voltage Stability Analysis-Definition and Criteria-Mechanism of Voltage Collapse-Static Analysis: V-Q sensitivity analysis, Q-V modal analysis-Determination of Shortest distance to instability-The continuation load flow analysis-Important voltage stability indices-Prevention of Voltage Collapse

Module 2

Concept of reliability, non-repairable components, hazard models, components with preventive maintenance, ideal repair and preventive maintenance, repairable components, normal repair and preventive maintenance.

System reliability, monotonic structures, reliability *of* series-parallel structures, the V out of 'rf configuration, the decomposition methods, minimal tie and cut method, state space method of system representation, system of two independent components, two components with dependent failures, combining states, non-exponential repair times failure effects analysis, State enumeration method, application to non-repairable systems.

Other methods of system reliability, fault free analysis. Monte Carlo simulation, planning for reliability, outage definitions, construction of reliability models.

Module 3

Generating capacity reserve evaluation, the generation model, the probability of capacity deficiency, the frequency and duration method, comparison of the reliability indices, generation expansion planning, uncertainties in generating unit failure rates and in load forecasts. Operating reserve evaluation, state space representation of generating units, rapid start and hot-reserve units, the security function approach.

Interconnected systems, two connected systems with independent loads, two connected system with correlated loads, more than two systems interconnected.

References:

1. K R Padiyar, *'Power System Dynamics',* 2nd Edition, B.S. Publishers, 2003
2. P. Kundur, *'Power system Stability and Control* McGraw-Hill Inc., 1994
3. T Van Cutsem, C Vournas, ' *Voltage Stability of Electric Power Systems',* Kluwer Academic Publishers, 1998
4. J JEndrenyi, *'Reliability modeling in electric power systems'* , John Wiley & Sons
5. Singh C, and Billinton R. *'System reliability modeling and evaluation',* Hutchinston,

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 3003 EHV AC&DC TRANSMISSION SYSTEM 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: To enable the students gain a fair knowledge on the concepts and technology of EHV AC & DC transmission systems

Module 1

EHV AC transmission-configuration-features-intermediate substations-applications- interconnected AC networks-HVDC system-classification-configuration-equipment in HVDC substations-Power flow in AC and HVDC lines-EHV AC vs HVDC-economic comparison-HVDC power flow- power conversion principle-power loss in DC system-steady state Ud/Id characteristics

Converter circuits-single phase and three phase circuits-analysis of bridge converter-with and without overlap-grid control- control characteristics-constant minimum ignition angle control-constant current control-extinction angle control

Harmonics-characteristics of harmonics-means of reducing harmonics-telephone interference-filters-single frequency and double frequency-tuned filters-DC harmonic filter

Module 2

Reactive power requirements in HVDC substations-effect of delay angle and extinction angle-short circuit ratio in planning of HVDC

DC line oscillations and line dampers-over voltage protection-DC lightning arresters-DC circuit breakers -basic concepts types & characteristics

Earth electrode-location and configuration-earth return-materials of anode-sea electrode –shore electrode-troubles by earth currents and remedial measures

Module 3

EHV AC Transmission-Components of transmission system-voltage gradients of conductor-single and bundled conductor

Corona & corona losses in EHVAC and HVDC-critical surface gradient-Peeks law-critical disruptive voltage and critical electric stress for visual corona-Insulation requirements of EHV AC and DC transmission lines -Electrostatic field of EHV lines-biological effects-live wire maintenance-insulation coordination-insulation for power frequency-voltage-switching over voltage-lightning performance-calculation of line & ground parameters

References:

1. EW Kimbark, *'Direct Current Transmission Volume - F* ,John Wiley -New York
2. Rakosh Das Begamudre, *'EHV AC Transmission Engineering'*, New Age International (p) Ltd., 2nd Edition, 1997
3. KR Padiyar, *'HVDC Power Transmission Systems'*, Wiley Eastern Ltd.
4. S.Rao, *'EHV AC and HVDC Transmission Engineering & Practice', Khanna Publishers Delhi.*

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 3004 STATIC VAR CONTROLLERS & HARMONIC FILTERING 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: To familiarize the different control schemes for static var compensators to mitigate power quality problems in Power System

Module 1

Fundamentals of Load Compensation , Steady-State Reactive Power Control in Electric Transmission Systems , Reactive Power Compensation and Dynamic Performance of Transmission Systems .

Converters for Static Compensation . Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM) . GTO Inverters . Multi-Pulse Converters and Interface Magnetics Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies. Multi-level inverters of Cascade Type and their modulation . Current Control of Inverters.

Module 2

Static Reactive Power Compensators and their control . Shunt Compensators, SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control, Series Compensators of Thyristor Switched and Controlled Type and their Control, SSSC and its Control, Sub-Synchronous Resonance and damping, Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power Systems

Module 3

Passive Harmonic Filtering . Single Phase Shunt Current Injection Type Filter and its Control, Three Phase Three-wire Shunt Active Filtering and their control using p-q theory and d-q modelling . Three-phase four-wire shunt active filters . Hybrid Filtering using Shunt Active Filters . Series Active Filtering in Harmonic Cancellation Mode . Series Active Filtering in Harmonic Isolation Mode . Dynamic Voltage Restorer and its control . Power Quality Conditioner

References

1. T.J.E Miller Reactive Power Control in Electric Systems John Wiley & Sons,1982.

2. N.G. Hingorani & L. Gyugyi Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. IEEE Press, 2000.

3. Ned Mohan et.al Power Electronics. John Wiley and Sons 2006

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPE 3005 POWER SYSTEM INSTRUMENTATION 3-0-0-3

Structure of the course

Lecture : 3Hrs /Week Credits: 3
Internal Assessment : 40 Marks.
End semester Examination : 60 Marks.

Course Objective: To impart principles of different measurement systems and methods of various electrical parameters.

Module 1

Generalized performance characteristics of instruments – Static and dynamic characteristics, development of mathematical model of various measurement systems. Classification of instruments based on their order. Dynamic response and frequency response studies of zero order, first order and second order instruments. Theory of errors: systematic and random errors, limits of error, probable error and standard deviation. Gaussian error curves, combination of errors.

Module 2

Transducers, classification & selection of transducers, strain gauges, inductive & capacitive transducers, piezoelectric and Hall-effect transducers, thermisters, thermocouples, photo-diodes & photo-transistors, encoder type digital transducers, signal conditioning and telemetry, basic concepts of smart sensors and application. Data Acquisition Systems.

Module 3

Measurement of voltage, current, phase angle, frequency, active power and reactive power in power plants. Energy meters and multipart tariff meters. Capacitive voltage transformers and their transient behavior, Current Transformers for measurement and protection, composite errors and transient response.

Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries

References

1. B D Doeblin, *'Measurement systems —Application and Design,* McGraw Hill New York.
2. John P. Bentley, *'Principles of Measurement System'* , Pearson Education .
3. J W Dally, W F Reley and K G McConnel, *'Instrumentation for Engineering measurements (second edition),* John Wiley & sons Inc New York, 1993
4. K. B. Klaasen, *'Electronic Measurement. And Instrumentation',* Cambridge University Press.
5. *Helfrick and Cooper, "Modern Electronic Instrumentation and Measurement Techniques", Prentice-Hall of India*
6. *Jones, B.E., "Instrumentation Measurement and Feedback", Tata McGraw-Hill, 1986.*
7. *Golding, E.W., "Electrical Measurement and Measuring Instruments", 3rd Edition*
8. Stuart A. Boyer: SCADA-Supervisory Control and Data Acquisition, Instrument Society of America Publications,USA,2004

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPI 3001   RENEWABLE ENERGY SOURCES AND TECHNOLOGY   3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: This subject provides sufficient knowledge about the promising new and renewable sources of energy so as to equip students capable of working with projects related to it and to take up research work in connected areas.

Module 1

Solar Thermal Systems : Solar radiation spectrum, radiation measurement, technologies. Applications: Heating, Cooling, Drying, Distillation, Power generation. Design consideration of solar water heater.

Solar Photovoltaic Systems : Operating principles, photovoltaic cell concepts, Cell, module, array, series and parallel connections, maximum power point tracking. Applications, Battery charging. Design of standalone PV system.

Fuel Cell: Principle of working, construction and applications.

Module 2

Wind Energy: Wind patterns and wind data, factors influencing wind, wind shear, turbulence, wind speed monitoring, Betz limit, WECS: classification, characteristics, applications, site selection. Types of windmills. Design of wind turbines. Characteristics of wind generators. Load matching

Microhydel :Operating principles, components of a microhydel power plant. types and characteristics of turbines, selection and modification, load balancing.

Module 3

Biomass: Operating principles, combustion and fermentation, types of biogas plants, applications, bio diesel
Ocean Energy: Ocean energy resources, principles of ocean thermal energy conversion systems, ocean thermal power plants- wave energy, characteristics, energy and power from the waves, wave energy conversion devices. Tidal power, energy estimation, site selection, types, tidal power plants.
Geothermal energy: Types of geothermal energy sites, site selection, geothermal power plants.

Reference

1. John W Twidell and Anthony D Weir, *Renewable energy sources*, English Language, Book society (ELBS), 1996
2. Godfrey Boyle, *Renewable Energy*, Oxford
3. D.P.Kothari, K.C.Singal, Rakesh Ranjan, *Renewable Energy Sources and Emerging Technologies*, Prentice Hall of India, New Delhi, 2009
4. B.H. Khan, *Non-Conventional Energy Resources, 2nd* ,Tata McGraw Hill, New Delhi, 2010
5. Chetan Singh Solanki, *Renewable Energy Technologies*, Prentice Hall of India, New Delhi, 2009
6. Tasneem Abbasi, S.A.Abbasi, *Renewable Energy Sources*, Prentice Hall of India, New Delhi, 2010
7. Siraj Ahmed, *Wind Energy- Theory and Practice*, Prentice Hall of India, New Delhi, 2010

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.

EPI 3002 ENERGY AUDITING & MANAGEMENT 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: Understanding, analysis and application of electrical energy management-measurement and accounting techniques-consumption patterns- conservation methods-application in industrial cases.

Module 1

System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments.
Electric motors-Energy efficient controls and starting efficiency-Motor Efficiency and Load Analysis- Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors.
Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing -Optimal operation and Storage; Case study

Module 2

Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study.
Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement-Maintenance, case study.
Peak Demand controls- Methodologies-Types of Industrial loads-Optimal Load scheduling-case study.
Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic ballast-Power quality issues-Luminaries, case study.

Module 3:

Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study; Electric loads of Air conditioning & Refrigeration-Energy conservation measures- Cool storage. Types-Optimal operation-case study; Electric water heating-Gysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls- software-EMS

References

1. Handbook on *Energy Audit and Environment Management* , Y P Abbi and Shashank Jain, TERI, 2006
2. Handbook of *Energy Audits*, Albert Thumann, William J. Younger, Terry Niehus, 2009
3. Giovanni Petrecca, *Industrial Energy Management: Principles and Applications.*, The Kluwer international series -207,1999
4. Anthony J. Pansini, Kenneth D. Smalling, *Guide to Electric Load Management.*, Pennwell Pub; (1998)
5. Howard E. Jordan, *Energy-Efficient Electric Motors and Their Applications*, Plenum Pub Corp; 2nd edition (1994)
6. Turner, Wayne C., *Energy Management Handbook*, Lilburn, The Fairmont Press, 2001
7. Albert Thumann , *Handbook of Energy Audits*, Fairmont Pr; 5th edition (1998)
8. IEEE Bronze Book- *Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities*, IEEE Inc, USA. 2008
9. Albert Thumann, P.W, *Plant Engineers and Managers Guide to Energy Conservation*- Seventh Edition-TWI Press Inc, Terre Haute, 2007
10. Donald R. W.,*Energy Efficiency Manual*, Energy Institute Press, 1986

Structure of the question paper

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EAI3001 AUTONOMOUS POWER SYSTEMS 3-0-0-3

Structure of the course

Lecture	: 3Hrs /Week	Credits: 3
Internal Assessment	: 40 Marks.	
End semester Examination	: 60 Marks.	

Course Objective: *Objectives of the course is to introduce autonomous power systems to students*

Module -1

Classification of EES systems -Roles of electrical energy storage (EES) system – Emerging needs for EES - Types and features of energy storage systems Mechanical storage systems - Pumped hydro storage (PHS) - Compressed air energy storage (CAES) - Flywheel energy storage (FES) - Electrochemical storage systems: Secondary batteries - Flow batteries - Chemical energy storage: Hydrogen (H2) - Synthetic natural gas (SNG) - Electrical storage systems: Double-layer capacitors (DLC) -Superconducting magnetic energy storage (SMES)- Thermal storage systems - Standards for EES - Technical comparison of EES technologies

Module -2

Captive Power Plants: Selection Considerations - Diesel Generator Captive Power Plants – Comparison of different types of captive power plants - Selection and Installation Factors - Sizing of a Genset: High Speed Engine or Slow/Medium Speed Engine, Capacity Combinations, Air Cooling Vs. Water Cooling, get over-heated during summer months - Safety Features - Parallel Operation with Grid- Maximum Single Load on DG Set - Unbalanced Load Effects - Neutral Earthing - Site Condition Effects on Performance Derating - Operational Factors - Load Pattern & DG Set Capacity - Sequencing of Loads - Load Pattern - Load Characteristics - Power Factor - Unbalanced Load Transient Loading

Module -3

SMPS- Characteristics – Steady state Analysis - Control methods:-Design of feedback compression
UPS: Necessity - types - typical layouts of UPS. Stand alone high quality Electronics Power Supplies

Combined Cycle Power Plant: Introduction - Typical cycles - Gas Turbine - G as Turbine HRSG Systems - Steam Turbine -Combined Cycle Plants -Availability and reliability

References:

1. Bueuru of Energy Efficiency, Study material for Energy manager programme, 2012
2. Irving M.Gottilieb “Power supplies, Switching Regulators, Inverters and Converters” BPB Publications – 1985
3. RK Chetty “Switched Power Supply Design” BPB Publication- 1987
4. Current Literature

Structure of the question paper

The question paper contains three questions from each module out of which two questions are to be answered by the student.