PONNAIYAH RAMAJAYAM INSTITUTE OF SCIENCE & TECHNOLOGY (PRIST)

Declared as DEEMED-TO-BE-UNIVERSITY
U/s 3 of UGC Act, 1956

**SCHOOL OF ENGINEERING AND TECHNOLOGY**

**DEPARTMENT OF ELECTRICAL &ELECTRONICS ENGINEERING**

**COURSE STRUCTURE R-2022**

# M.TECH-POWER SYSTEMS (FULL TIME)

## [Regulation 2022]

[for candidates admitted to M. Tech Power Systemprogram from Jun 2022 onwards]

## 1. PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

| | |
|---|---|
| **PEO 1** | To prepare the students for successful career in electrical power industry, research and teaching institutions. |
| **PEO 2** | To provide strong foundation in Power Engineering, necessary for day-to-dayoperation and planning of Power System. |
| **PEO 3** | To develop the ability to design various controllers to enhance the stability and powertransfer capability of the Power System. |
| **PEO 4** | To provide knowledge in Renewable Energy Systems, Electric Vehicles and Grid Integrations using Power Converters. |
| **PEO 5** | To develop a detailed understanding of various tools applied to the operation, designand investigation of modern electric power systems. |

## 2. PROGRAMME OUTCOMES (POs):

| PO | Programme Outcomes |
|---|---|
| **PO 1** | An ability to independently carry out research/investigation and development work to solve practical problems |
| **PO 2** | An ability to write and present a substantial technical report/document |
| **PO 3** | Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a levelhigher than the requirements in the appropriate bachelor program |
| **PO 4** | Ability to attain professional ethics and intellectual integrity to contribute tothe community for sustainable development of society |
| **PO 5** | Apply knowledge of basic science and engineering in analysis and modelingof the power system components |
| **PO 6** | Implement cost effective and cutting edge technologies in Power System |

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

**PROGRAMME: M.TECH-POWER SYSTEMS (FULL TIME)**

**CURRICULUM -REGULATION 2022**

**SEMESTER – I**

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1. | 22248S11D | Applied Mathematics for Power System Engineering | 3 | 1 | 0 | 4 |
| 2 | 22272C12 | System Theory | 3 | 1 | 0 | 4 |
| 3 | 22272C13 | Advanced Power System Analysis | 3 | 1 | 0 | 4 |
| 4 | 22272C14 | Economic Operations of Power Systems | 3 | 1 | 0 | 4 |
| 5 | 22272C15 | HVDC and FACTS | 3 | 1 | 0 | 4 |
| 6 | 22272E16_ | Elective-I | 3 | 0 | 0 | 3 |
| 7 | 22272L17 | Power System Simulation Laboratory | 0 | 0 | 3 | 3 |
| | | **TOTAL** | | | | **26** |

**SEMESTER – II**

| SL. NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272C21 | EHV power transmission | 3 | 1 | 0 | 4 |
| 2 | 22272C22 | Power System Control | 3 | 1 | 0 | 4 |
| 3 | 22272C23 | Advanced Power System Protection | 3 | 1 | 0 | 4 |
| 4 | 22272E24_ | Elective –II | 3 | 0 | 0 | 3 |
| 5 | 22272E25_ | Elective –III | 3 | 0 | 0 | 3 |
| 6 | 22272L26 | Advanced Power System Simulation Laboratory | 0 | 0 | 3 | 3 |
| 7 | 222TECWR | Technical Writing/Seminars | 0 | 0 | 3 | 3 |
| | | **TOTAL** | | | | **24** |

**SEMESTER – III**

| SL. NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272C31 | Electrical Transients in power systems | 3 | 1 | 0 | 4 |
| 2 | 22272E32_ | Elective –IV | 3 | 0 | 0 | 3 |
| 3 | 22272E33_ | Elective –V | 3 | 0 | 0 | 3 |
| 4 | 22272E34_ | Elective –VI | 3 | 0 | 0 | 3 |
| 5 | 22272P35 | Project work Phase-I | 0 | 0 | 10 | 10 |
| | | **TOTAL** | | | | **23** |

**SEMESTER – IV**

| SL. NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272P41 | Project work Phase-II | 0 | 0 | 15 | 15 |

## Elective –I

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272E16A | Analysis of Inverters | 3 | 0 | 0 | 3 |
| 2. | 22272E16B | Modeling and Analysis of Electrical Machines | 3 | 0 | 0 | 3 |
| 3. | 22272E16C | Advanced Power System Dynamics | 3 | 0 | 0 | 3 |
| 4. | 22272E16D | Analysis and Computation of Electromagnetic Transients in Power Systems | 3 | 0 | 0 | 3 |

## Elective –II

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272E24A | Smart Grid | 3 | 0 | 0 | 3 |
| 2. | 22272E24B | Solar and Energy Storage Systems | 3 | 0 | 0 | 3 |
| 3. | 22272E24C | Power System Reliability | 3 | 0 | 0 | 3 |
| 4. | 22272E24D | Distributed Generation and Microgrid | 3 | 0 | 0 | 3 |

## Elective –III

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272E25A | Wind Energy conversion systems | 3 | 0 | 0 | 3 |
| 2. | 22272E25B | AI Techniques to Power Systems | 3 | 0 | 0 | 3 |
| 3. | 22272E25C | Electrical Distribution | 3 | 0 | 0 | 3 |
| 4. | 22272E25D | Energy Management and Auditing | 3 | 0 | 0 | 3 |

## Elective –IV

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272E32A | Power Electronics applications in Power systems | 3 | 0 | 0 | 3 |
| 2. | 22272E32B | Power system Dynamics | 3 | 0 | 0 | 3 |
| 3. | 22272E32C | Electric Vehicles and Power Management | 3 | 0 | 0 | 3 |
| 4. | 22272E32D | Electromagnetic Interference and Compatibility | 3 | 0 | 0 | 3 |

**Elective –V**

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272E33A | Power Conditioning | 3 | 0 | 0 | 3 |
| 2. | 22272E33B | Deregulated Power System | 3 | 0 | 0 | 3 |
| 3. | 22272E33C | Control System Design for Power Electronics | 3 | 0 | 0 | 3 |
| 4. | 22272E33D | Principles of EHV Transmission | 3 | 0 | 0 | 3 |

**Elective –VI**

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 22272E34A | Software for Control system Design | 3 | 0 | 0 | 3 |
| 2. | 22272E34B | Industrial Power system analysis and design | 3 | 0 | 0 | 3 |
| 3. | 22272E34C | Soft Computing Techniques | 3 | 0 | 0 | 3 |
| 4. | 22272E34D | Restructured Power System | 3 | 0 | 0 | 3 |

**Total Credits = 88**

# Credit Distribution

| Sem. | Core Courses | | | | Elective Courses | | Total Credits |
|---|---|---|---|---|---|---|---|
| | Theory Courses | | Practical Courses | | | | |
| | Nos. | Credits | Nos. | Credits | Nos. | Credits | |
| I | 04 | 16 | 01 | 03 | 01 | 03 | 26 |
| II | 03 | 12 | 02 | 06 | 02 | 06 | 24 |
| III | 01 | 04 | - | - | 03 | 09 | 23 |
| IV | - | - | - | - | - | - | 15 |
| **Total Credits** | | | | | | | **88** |

**22248S11D - APPLIED MATHEMATICS for POWER SYSTEM ENGINEERING**

**ENGINEERING** **3 1 0 4**

**OBJECTIVES :**

- To develop the ability to apply the concepts of matrix theory in Electrical Engineering problems.
- To familiarize the students in the field of differential equations to solve boundary value problems associated with engineering applications.
- To develop the ability among the students to solve problems using Fourier series associated with engineering applications.
- To impart deep knowledge and concepts to solve complicated problems using linear programming.
- To develop the capability of solving problems using non - linear programming techniques.

**1. ADVANCED MATRIX THEORY** **9**

Matrix norms – Jordan canonical form – Generalized eigenvectors – Singular value decomposition – Pseudo inverse – Least square approximations.

**2. RANDOM PROCESSES** **9**

Random variable, discrete, continuous types - Binomial, Poisson, normal and exponential distributions density & distribution Functions- Moments Moment Generating Functions – Notion of stochastic processes - Auto-correlation – Cross correlation .

**3. LINEAR PROGRAMMING** **9**

Basic concepts – Graphical and Simplex methods –Transportation problem – Assignment problem.

**4. DYNAMIC PROGRAMMING** **9**

Elements of the dynamic programming model – optimality principle – Examples of dynamic programming models and their solutions.

**5. INTEGRAL TRANSFORMS** **9**

Finite Fourier transform - Fourier series - Finite sine Transform - Cosine transform - finite Hankel transform - definition, Transform of df/dx where p is a root of Jn(p) = 0, Transform of

$$\frac{d^2f}{dx^2} + \frac{1}{x}\frac{df}{dx}, \text{ and Transform of } \frac{d^2f}{dx^2} + \frac{1}{x}\frac{df}{dx} - \frac{n^2f}{x^2}$$

***L = 45 T = 15 P = 0 C =4***

**OUTCOMES :**

- Student can able to apply the concepts of matrix theory in Electrical Engineeringproblems.
- Students can be easily understood to solve boundary value problems associatedwith engineering applications.
- Able to solve problems using Fourier series associated with engineering applications.
- Able to understood the basic concepts and also to solve complicated problems using linear programming.
- Student have capability of solving problems using non - linear programming techniques.

**REFERENCES**


1. Lewis.D.W., Matrix Theory ,Allied Publishers, Chennai 1995.
2. Bronson, R, Matrix Operations, Schaums outline Series, McGraw Hill, New York. 1989.
3. Andrews, L.A., and Shivamoggi B.K., “Integral Transforms for Engineers and Applied Mathematicians”, Macmillan , New York ,1988.
4. Taha, H.A., " Operations research - An Introduction ", Mac Millan publishing Co., (1982).
5. Gupta, P.K.and Hira, D.S., " Operations Research ", S.Chand & Co., New Delhi, (1999).6..
6. Ochi, M.K. " Applied Probability and Stochastic Processes ", John Wiley & Sons (1992).
7. Peebles Jr., P.Z., " Probability Random Variables and Random Signal Principles, McGraw Hill Inc., (1993).


**MAPPING OF CO’S WITH PO’S**

| CO | PO | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 3 | 2 | 2 | 1 | 3 | 1 |
| 2 | 3 | 2 | 2 | 1 | 3 | 1 |
| 3 | 3 | 2 | 2 | 1 | 3 | 1 |
| 4 | 3 | 2 | 2 | 1 | 3 | 1 |
| 5 | 3 | 2 | 2 | 1 | 3 | 1 |
| AVG | 3 | 2 | 2 | 1 | 3 | 1 |

## 22272C12- SYSTEM THEORY

**3 1 0 4**

**OBJECTIVES:**

1. To educate on modeling and representing systems in state variable form.
2. To train on solving linear and non-linear state equations.
3. To illustrate the properties of control system.
4. To classifynon–linearitiesand examine stability of systems in the sense of Lyapunov's theory.
5. To educate on modal concepts, design of state, output feedback controllers and estimators.

**1. PHYSICAL SYSTEMS AND STATE ASSIGNMENT** **9**

Systems - electrical - mechanical - hydraulic - pneumatic - thermal systems - modelling of some typical systems like D.C. Machines - inverted pendulum.

**2. STATE SPACE ANALYSIS** **9**

Realisation of state models - non-uniqueness - minimal realisation - balanced realisation - solution of state equations - state transition matrix and its properties - free and forced responses - properties - controllability and observability - stabilisability and detectability - Kalman decomposition.

**3. MIMO SYSTEMS - FREQUENCY DOMAIN DESCRIPTIONS** **9**

Properties of transfer functions - impulse response matrices - poles and zeros of transfer function matrices - critical frequencies - resonance - steady state and dynamic response - bandwidth - Nyquist plots - singular value analysis.

**4. NON-LINEAR SYSTEMS** **9**

Types of non-linearity - typical examples - equivalent linearization - phase plane analysis - limit cycles - describing functions - analysis using describing functions - jump resonance.

**5. STABILITY** **9**

Stability concepts - equilibrium points - BIBO and asymptotic stability - direct method of Liapunov - application to non-linear problems - frequency domain stability criteria - Popov's method and its extensions.

***L = 45 T = 15 P = 0 C =4***

**OUTCOMES:**

Students able to

CO1 Understand the concept of State-State representation for Dynamic Systems
CO2 Explain the solution techniques of state equations
CO3 Realize the properties of control systems in state space form
CO4 Identify non-linearities and evaluate the stability of the system using Lyapnov notion
CO5 Perform Modal analysis and design controller and observer in state space form

**REFERENCES**


1. M. Gopal, 'Modern Control Engineering', Wiley, 1996.
2. J.S. Bay, 'Linear State Space Systems', McGraw-Hill, 1999.
3. Eroni-Umez and Eroni, 'System dynamics & Control', Thomson Brooks / Cole, 1998.
4. K. Ogatta, 'Modern Control Engineering', Pearson Education, Low Priced Edition, 1997.
5. G.J. Thaler, 'Automatic control systems', Jaico publishers, 1993.
6. John S. Bay, 'Linear State Space Systems', McGraw-Hill International Edition, 1999.


| CO | PO | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 3 | - | 2 | 2 | 3 | - |
| 2 | 2 | 2 | 3 | - | 2 | 3 |
| 3 | 3 | - | 3 | - | - | - |
| 4 | 3 | - | 3 | 2 | 2 | - |
| 5 | 3 | - | 3 | 2 | 3 | 2 |
| AVG | 2.8 | 2 | 2.8 | 3 | 2.5 | 2.5 |

## 22272C13 - ADVANCED POWER SYSTEM ANALYSIS

**3 1 0 4**

**OBJECTIVES:**

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

**UNIT I SOLUTION TECHNIQUE 9**

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

**UNIT II POWER FLOW ANALYSIS 9**

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

**UNIT III OPTIMAL POWER FLOW 9**

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

**UNIT IV SHORT CIRCUIT ANALYSIS 9**

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

**UNIT V TRANSIENT STABILITY ANALYSIS 9**

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

***L = 45 T = 15 P = 0 C =4***

**OUTCOMES:**

- Ability to apply the concepts of sparse matrix for large scale power system analysis
- Ability to analyze power system studies that needed for the transmission system planning.

**REFERENCES:**

1. A.J.Wood and B.F.Wollenberg, “Power Generation Operation and Control”, John Wiley and sons, New York, 1996.
2. W.F.Tinney and W.S.Meyer, “Solution of Large Sparse System by Ordered Triangular Factorization” IEEE Trans. on Automatic Control, Vol : AC-18, pp:333346 Aug 1973.
3. K.Zollenkopf, “Bi-Factorization: Basic Computational Algorithm and Programming Techniques ; pp:75-96 ; Book on “Large Sparse Set of Linear Systems” Editor: J.K.Rerd,Academic Press, 1971.
4. M.A.Pai,” Computer Techniques in Power System Analysis”,Tata McGraw-Hill Publishing Company Limited, New Delhi, 2006.
5. G W Stagg , A.H El. Abiad, “Computer Methods in Power System Analysis”, McGraw Hill, 1968.
6. P.Kundur, “Power System Stability and Control”, McGraw Hill, 1994.

## 22272C14- ECONOMIC OPERATIONS OF POWER SYSTEMS

**3 1 0 4**

**1. INTRODUCTION** **9**

Planning and operational problems of power systems – review of economic dispatch and calculation using B matrix loss formula – use of participation factors in on line economic dispatch.

**2. OPTIMAL POWER FLOW PROBLEM** **9**

Real and reactive power control variables – operation and security constraints and their limits – general OPF problem with different objective functions – formulation – cost loss minimization using Dommel and Tinney's method and SLP – development of model and algorithm – MVAR planning – optimal sitting and sizing of capacitors using SLR method – interchange evaluation using SLP.

**3. HYDRO THERMAL SCHEDULING** **9**

Problems definition and mathematical model of long and short term problems – discretization – dynamic and incremental dynamic programming – methods of local variation – hydro thermal system with pumped hydro units – solution by local variation treating pumped hydro unit for load management and spinning reserve.

**4. UNIT COMMITMENT** **9**

Constraints in unit commitment – solution by priority list method – dynamic programming method – backward and forward – restricted search range.

**5. MAINTENANCE SCHEDULING** **9**

Factors considered in maintenance scheduling for generating units – turbines – boilers – introduction to maintenance scheduling using mathematical programming.

***L = 45 T = 15 P = 0 C =4***

**REFERENCES**

1. Allen J.Wood and Bruce F.Wollenberg, "Power generation and control", John Wiley & Sons, New York, 1984.
2. Krichmayer L., "Economic operation of power systems", John Wiley and sons Inc, New York, 1958.
3. Krichmayer L.K, "Economic control of Interconnected systems", Jhon Wiley and sons Inc, New York, 1959.
4. Elgerd O.I., "Electric energy systems theory – an introduction", McGraw Hill, New Delhi, 1971.

## MAPPING OF CO'S WITH PO'S

| CO | PO | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 2 | - | 3 | - | 3 | - |
| 2 | 3 | - | 3 | - | 3 | 3 |
| 3 | 3 | 1 | 3 | 2 | 2 | 2 |
| 4 | 3 | - | 3 | - | - | 3 |
| 5 | 3 | 1 | 3 | 3 | 3 | 2 |
| AVG | 2.8 | 1 | 3 | 2.5 | 2.75 | 2.5 |

## 22272C15- HVDC AND FACTS

**3 1 0 4**

**OBJECTIVES:**

- To emphasis the need for FACTS controllers.
- To learn the characteristics, applications and modeling of series and controllers.
- To analyze the interaction of different FACTS controller and coordination
- To impart knowledge on operation, modelling and control of HVDC link.
- To perform steady state analysis of AC/DC system.

**UNIT I INTRODUCTION 9**

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

**UNIT II SVC & STATCOM 9**

Configuration of SVC- voltage regulation by SVC- Modelling of SVC for load flow analysisDesign of SVC to regulate the mid-point voltage of a SMIB system- Applications Static synchronous compensator (STATCOM )- Operation of STATCOM – Voltage regulation – Power flow control with STATCOM.

**UNIT III TCSC and SSSC 9**

Concepts of Controlled Series Compensation- Operation of TCSC - Analysis of TCSC operation - Modelling of TCSC for load flow studies - Static synchronous series compensator (SSSC)- Operation of SSSC - Modelling of SSSC for power flow – operation of Unified power flow controllers(UPFC ).

**UNIT IV ANALYSIS OF HVDC LINK 9**

Simplified analysis of six pulse Graetz bridge – Charecteristics - Analysis of converter operations – Commutation overlap – Equivalence circuit of bipolar DC transmission link – Modes of operation – Mode ambiguity – Different firing angle controllers – Power flow control.

**UNIT V POWER FLOW ANALYSIS IN AC/DC SYSTEMS 9**

Per unit system for DC Quantities - Modelling of DC links - Solution of DC load flow - Solution of AC-DC power flow – Unified and Sequential methods.

**TOTAL : 45 PERIODS**

**OUTCOMES:**

- Learners will be able to refresh on basics of power transmission networks and need for FACTS controllers
- Learners will understand the significance about different voltage source converter based FACTS controllers
- Learners will understand the significance of HVDC converters and HVDC system control
- Learners will attain knowledge on AC/DC power flow analysis

**REFERENCES**

1. Mohan Mathur, R., Rajiv. K. Varma, “Thyristor – Based Facts Controllers for Electrical Transmission Systems”, IEEE press and John Wiley & Sons, Inc.

2. K.R.Padiyar, “FACTS Controllers in Power Transmission and Distribution”, New Age International (P) Ltd., Publishers, New Delhi, Reprint 2008.
3. K.R.Padiyar, “HVDC Power Transmission Systems”, New Age International (P) Ltd., New Delhi, 2002.
4. J.Arrillaga, “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 1983.
5. V.K.Sood, “HVDC and FACTS controllers- Applications of Static Converters in Power System”, Kluwer Academic Publishers 2004

**MAPPING OF CO’S WITH PO’S**

| | PO | | | | | |
|---|---|---|---|---|---|---|
| **CO** | **1** | **2** | **3** | **4** | **5** | **6** |
| **CO1** | 3 | 2 | 1 | - | 1 | - |
| **CO2** | 1 | 1 | 2 | - | 3 | - |
| **CO3** | 2 | - | 3 | 1 | 1 | 2 |
| **CO4** | 3 | 3 | 1 | 2 | - | 1 |
| **CO5** | 2 | 2 | 2 | - | 3 | - |
| **AVG** | 2.2 | 2 | 1.8 | 1.5 | 2.33 | 1.5 |

**22272L17- POWER SYSTEM SIMULATION LABORATORY 0 0 3 3**

**OBJECTIVES:**

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

**LIST OF EXPERIMENTS**

1. Power flow analysis by Newton-Raphson method and Fast decoupled method

2. Transient stability analysis of single machine-infinite bus system using classical machine model

3. Contingency analysis: Generator shift factors and line outage distribution factors

4. Economic dispatch using lambda-iteration method

5. Unit commitment: Priority-list schemes and dynamic programming

6. State Estimation (DC)

7. Analysis of switching surge using EMTP: Energisation of a long distributed- parameter line

8. Analysis of switching surge using EMTP : Computation of transient recovery voltage

9. Simulation and Implementation of Voltage Source Inverter

10. Digital Over Current Relay Setting and Relay Coordination using Suitable software packages

11 Co-ordination of over-current and distance relays for radial line protection

**TOTAL: 60 PERIODS**

**OUTCOMES:**

- Upon Completion of the course, the students will be able to:
- Analyze the power flow using Newton-Raphson method and Fast decoupled method.
- Perform contingency analysis & economic dispatch
- Set Digital Over Current Relay and Coordinate Relay

**MAPPING O CO'S WITH PO'S**

| CO | PO | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 3 | - | 3 | - | - | 3 |
| 2 | 3 | 2 | 3 | - | 3 | 2 |
| 3 | 3 | - | 3 | 3 | 3 | - |
| AVG | 3 | 2 | 3 | 3 | 3 | 2.5 |

*SEMESTER –II*

**22272C21- EHV POWER TRANSMISSION**

**3 1 0 4**

**1. INTRODUCTION 9**

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

**2. CALCULATION OF LINE PARAMETERS 9**

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

**3. VOLTAGE GRADIENTS OF CONDUCTORS 9**

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

**4. CORONA EFFECTS 9**

Power losses and audible losses: I R loss and corona loss - audible noise generation and characteristics - limits for audible noise - Day-Night equivalent noise level- radio interference: corona pulse generation and properties - limits for radio interference fields

**5. ELECTROSTATIC FIELD OF EHV LINES 9**

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

***L = 45 T = 15 P = 0 C =4***

**COURSEOUTCOMES:**

CO1: Ability to analyse the identify voltage level and line configurations CO2: Ability to model EHV AC and HVDC lines

CO3: Ability to compute voltage gradients of transmission line conductors

CO4: Ability to analyze the effects of electrostatic field on living and nonliving organisms

CO5: Ability to analyze the design, control and protection aspects of HVDC lines.

**REFERENCES**

1. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", Second Edition, New Age International Pvt. Ltd., 1990.

2. Power Engineer's Handbook, Revised and Enlarged 6th Edition, TNEB Engineers' Association, October 2002.

3. Microtran Power System Analysis Corporation, Microtran Reference Manual, Vancouver Canada. (Website: www.microtran.com).

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 |
|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 3 | | 3 | |
| **CO2** | 3 | 3 | 3 | 3 | 3 | | |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 3 | |
| **CO4** | 3 | 3 | 3 | 3 | | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 | |
| **AVG.** | **3** | **3** | **3** | **3** | **1.8** | **2.4** | **0.6** |

4.

*SEMESTER – II*

**22272C22** **POWER SYSTEM CONTROL** **3 1 0 4**

**3 0 0 3**

**OBJECTIVES**

- To understand the fundamentals of speed governing system and the concept of control areas.
- To get the insight of load frequency control and itsmodelling.
- To provide knowledge about Hydrothermal scheduling, Unit commitment and solution techniques.
- To realize the requirements and methods of real and reactive power control in power system.
- To be familiar with the power system security issues and contingency studies.

**1. AUTOMATIC GENERATION CONTROL 9**

Plant and system level control problem – ALFC of single area system modeling state and transient response – EDC control loop – ALFC of multi area system – modeling – static and transient response of two area system development of state variable model – two area system – AGC system design Kalman's method.

**2. AUTOMATIC VOLTAGE CONTROL 9**

Modeling of AVR loop – components – dynamic and static analysis – stability compensation – system level voltage control using OLTC, capacitor and generator voltages – expert system application for system voltage control.

**3. SECURITY CONTROL CONCEPT 9**

System operating states by security control functions – monitoring evaluation of system state by contingency analysis – corrective controls (preventive, emergency and restorative) – islanding scheme.

**4. STATE ESTIMATION 9**

Least square estimation – basic solution – sequential form of solution – static state estimation of power system by different algorithms – tracking state estimation of power system- computation consideration – external equivalency. Treatment of bad data and on line load flow analysis.

**5. COMPUTER CONTROL OF POWER SYSTEM 9**

Energy control center – various levels – national – regional and state level SCADA system – computer configuration – functions, monitoring, data acquisition and controls – EMS system – software in EMS system. Expert system applications for power system operation.

**L = 45 T = 15 P = 0 C =4**

**OUTCOMES:**

Students able to

CO1: Explain about the operation and control of power system and List the past and present status of Indian power sector

CO2: Develop the static and dynamic model of Load Frequency Control in single and two area system

CO3: Analyse the problems associated with hydro thermal Scheduling and to construct the algorithm for feasible load management

CO4: Distinguish between various methods involved in unit commitment and economic dispatch problems

CO5: Define about the power system security factors and analyse the algorithms used for optimal power flow

## REFERENCES


1. Kundur.P., “power system stability and control”, McGraw Hill, 1994.
2. Anderson P.M., and Fouad A.A, “power system control and stability”, Galgotia publication, New Delhi, 1981.
3. Taylor C.W., “power systems voltage stability”, McGraw Hill, New Delhi, 1993.
4. IEEE recommended practice for excitation system models for power system stability studies, IEEE standard 421.5, 1992.
5. Kimbark E.W., “power system stability”, Vol.3., Synchronous machines, John Wiley and sons, 1956.
6. T.V Custem, C.Vournas, “voltage stability of power system”, Kluwer Acadamic Publishers, 1998.
7. Elgerd O.L., “Elctric energy systems theory – an introduction”, McGraw Hill, New Delhi, 1971


## MAPPING O CO’S WITH PO’S

| CO | PO | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
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| 3 | 1 | 2 | - | 1 | 2 | 3 |
| 4 | 2 | 1 | - | 2 | 2 | 3 |
| 5 | 1 | 2 | - | - | 2 | 3 |
| AVG | 1.34 | 2 | - | 1.67 | 2.2 | 2.75 |

8. .

**22272C23- ADVANCED POWER SYSTEM PROTECTION**

**3 1 0 4**

**OBJECTIVES:**

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

**UNIT I OVER CURRENT & EARTH FAULT PROTECTION 9**

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

**UNIT II TRANSFORMER & BUSBAR PROTECTION 9**

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

**UNIT III DISTANCE AND CARRIER PROTECTION OF TRANSMISSION LINES 9**

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

**UNIT IV GENERATOR PROTECTION 9**

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

**UNIT V NUMERICAL PROTECTION**

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

***L = 45 T = 15 P = 0 C =4***

**TOTAL : 45 PERIODS**

**COURSE OUTCOMES:**

**Students able to**

**CO1** Familiarize the underlying principle of digital techniques for power system protection

**CO2** Design the relaying scheme for protection of power apparatus using digital techniques

**CO3** Evaluate and interpret relay coordination

**CO4** Develop PC based algorithm for short circuit studies

**CO5** Compare the performance of modern protection schemes with the conventional schemes

1 Y.G. Paithankar and S.R Bhide, "Fundamentals of Power System Protection", Prentice-Hall of India, 2003

2 Badri Ram and D.N. Vishwakarma, "Power System Protection and Switchgear", Tata McGraw- Hill Publishing Company, 2002.

3 T.S.M. Rao, "Digital Relay / Numerical relays", Tata McGraw Hill, New Delhi, 1989.

4 P.Kundur, "Power System Stability and Control", McGraw-Hill, 1993.

**MAPPING OF CO'S WITH PO'S**

| CO | PO | | | | | |
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| 5 | 3 | 1 | 3 | 3 | 3 | 2 |
| AVG | 2.8 | 1 | 3 | 2.5 | 2.75 | 2.5 |

## 22272L26 ADVANCED POWER SYSTEM SIMULATION LABORATORY

**L T P C**

**0 0 4 2**

**OBJECTIVES:**

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

**LIST OF EXPERIMENTS**

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

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| 5 | 3 | - | 3 | 2 | 2 | 3 |
| AVG | 3 | 2 | 3 | 2 | 2.4 | 2.6 |

## 22272C31- ELECTRICAL TRANSIENTS IN POWER SYSTEMS

**3 1 0 4**

**1. TRAVELLING WAVES ON TRANSMISSION LINE 9**

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behavior of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion – Multi-conductor system and Velocity wave.

**2. COMPUTATION OF POWER SYSTEM TRANSIENTS 9**

Principle of digital computation – Matrix method of solution, Modal analysis, Z transforms, Computation using EMTP – Simulation of switches and non-linear elements.

**3. LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES 9**

Lightning: Physical phenomena of lightning – Interaction between lightning and power system – Factors contributing to line design – Switching: Short line or kilometric fault – Energizing transients - closing and re-closing of lines - line dropping, load rejection - Voltage induced by fault – Very Fast Transient Overvoltage (VFTO)

**4. BEHAVIOUR OF WINDING UNDER TRANSIENT CONDITION 9**

Initial and Final voltage distribution - Winding oscillation - traveling wave solution - Behavior of the transformer core under surge condition – Rotating machine – Surge in generator and motor

**5. INSULATION CO-ORDINATION 9**

Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated Substation (GIS), insulation level, statistical approach, co-ordination between insulation and protection level –overvoltage protective devices – lightning arresters, substation earthing.

**L = 45 T = 15 P = 0 C =4**

**REFERENCES**

1. Pritindra Chowdhari, "Electromagnetic transients in Power System", John Wiley and Sons Inc., 1996.
2. Allan Greenwood, "Electrical Transients in Power System", Wiley & Sons Inc. New York, 1991.
3. Klaus Ragaller, "Surges in High Voltage Networks", Plenum Press, New York, 1980.
4. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", (Second edition) Newage International (P) Ltd., New Delhi, 1990.
5. Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.
6. IEEE Guide for safety in AC substation grounding IEEE Standard 80-2000.
7. Working Group 33/13-09 (1988), 'Very fast transient phenomena associated with Gas Insulated System', CIGRE, 33-13, pp. 1-2

**MAPPING OF CO'S WITH PO'S**

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| 5 | 3 | 1 | 3 | 3 | 3 | 2 |
| AVG | 2.8 | 1 | 3 | 2.5 | 2.75 | 2.5 |

**22272E16A – ANALYSIS of INVERTERS** **L T P C**
**3 0 0 3**

**OBJECTIVES:**

- To determine the operationand characteristics of controlled rectifiers.
- To apply switching techniques and basic topologies of DC-DC switching regulators.
- To introduce the design of power converter components.
- To provide an in depth knowledge about resonant converters.
- To comprehend the conceptsof AC-AC power converters and their applications.

**UNIT I SINGLE PHASE & THREE PHASE CONVERTERS 9**

Principle of phase controlled converter operation – single-phase full converter and semi-converter (RL,RLE load)- single phase dual converter – Three phase operation full converter and semi-converter (R,RL,RLE load) – reactive power – power factor improvement techniques – PWM rectifiers.

**UNIT II DC-DC CONVERTERS 9**

Limitations of linear power supplies, switched mode power conversion, Non-isolated DC-DC converters: operation and analysis of Buck, Boost, Buck-Boost, Cuk& SEPIC – under continuous and discontinuous operation – Isolated converters: basic operation of Flyback, Forward and Push-pull topologies.

**UNIT III DESIGN OF POWER CONVERTER COMPONENTS 9**

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

**UNIT IV RESONANT DC-DC CONVERTERS 9**

Switching loss, hard switching, and basic principles of soft switching- classification of resonant converters- load resonant converters – series and parallel – resonant switch converters – operation and analysis of ZVS, ZCS converters comparison of ZCS/ZVS-Introduction to ZVT/ZCT PWM converters.

**UNIT V AC-AC CONVERTERS 9**

Principle of on-off and phase angle control – single phase ac voltage controller – analysis with R & RL load – Three phase ac voltage controller – principle of operation of cyclo converter – single phase and three phase cyclo converters – Introduction to matrix converters.

**TOTAL : 45 PERIODS**

**OUTCOMES:**

At the end of the course the student will be able to:

- Analyze various single phase and three phase power converters
- Select and design dc-dc converter topologies for a broad range of power conversion applications.
- Develop improved power converters for any stringent application requirements.
- Design ac-ac converters for variable frequency applications.

**TEXT BOOKS:**

1. Ned Mohan,T.MUndeland and W.P Robbin, "Power Electronics: converters, Application and design" John Wiley and sons.Wiley India edition, 2006.
2. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Prentice Hall India, Third Edition, New Delhi, 2004.
3. P.C. Sen, "Modern Power Electronics", Wheeler Publishing Co, First Edition, New Delhi, 1998.
4. P.S.Bimbra, "Power Electronics", Khanna Publishers, Eleventh Edition, 2003
5. Simon Ang, Alejandro Oliva, "Power-Switching Converters, Second Edition, CRC Press, Taylor & Francis Group, 2010
6. V.Ramanarayanan, "Course material on Switched mode power conversion", 2007
7. Alex Van den Bossche and VencislavCekovValchev, "Inductors and TransformersforPowerElectronics", CRC Press, Taylor & Francis Group, 2005
8. W. G. Hurley and W. H.Wolfle, "Transformers and Inductors for Power Electronics Theory, Design and Applications", 2013 John Wiley & Sons Ltd.
9. Marian.K.Kazimierczuk and DariuszCzarkowski, "Resonant Power Converters", John Wiley & Sons limited, 2011

**CO-PO MAPPING :**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO1 | 3 | | 3 | 3 | 2 | 2 |
| CO2 | 3 | | 3 | 3 | 2 | 2 |
| CO3 | 3 | | 3 | 3 | 2 | 2 |
| CO4 | 3 | | 3 | 3 | 2 | 2 |
| CO5 | 3 | | 3 | 3 | 2 | 2 |

## 22272E16B - MODELLING AND ANALYSIS OF ELECTRICAL MACHINES

**3 1 0 4**

**UNIT I PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION**

General expression of stored magnetic energy - co-energy and force/torque - example using single and doubly excited system.

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**UNIT II BASIC CONCEPTS OF ROTATING MACHINES**

Calculation of air gap M.M.F. - per phase machine inductance using physical machine data - voltage and torque equation of D.C. machine - three phase symmetrical induction machine and salient pole synchronous machines in phase variable form.

**UNIT III INTRODUCTION TO REFERENCE FRAME THEORY**

Static and rotating reference frames - transformation relationships - examples using static symmetrical three phase R, R-L, R-L-M and R-L-C circuits - application of reference frame theory to three phase symmetrical induction and synchronous machines - dynamic direct and quadrature axis model in arbitrarily rotating reference frames - voltage and torque equations - derivation of steady state phasor relationship from dynamic model - generalized theory of rotating electrical machine and Kron's primitive machine.

**UNIT IVD ETERMINATIONOF SYNCHRONOUS MACHINE DYNAMIC EQUIVALENT CIRCUIT PARAMETERS**

Standard and derived machine time constants - frequency response test - analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine.

**UNIT V SPECIAL MACHINES**

Permanent magnet synchronous machine - surface permanent magnet (square and sinusoidal back E.M.F. type) and interior permanent magnet machines - construction and operating principle - dynamic modeling and self controlled operation - analysis of switch reluctance motors.

***L = 45 T = 15 P = 0 C =4***

**TEXT BOOKS**

1. Charles Kingsley, A.E. Fitzgerald Jr. and Stephen D. Umans, 'Electric Machinery', Tata McGraw-Hill, Fifth Edition, 1992.
2. R. Krishnan, 'Electric Motor & Drives: Modelling, Analysis and Control', Prentice Hall of India, 2001.

**REFERENCES**

1. C.V. Jones, 'The Unified Theory of Electrical Machines', Butterworth, 1967.
2. T.J.E. Miller, 'Brushless Permanent Magnet and Reluctance Motor Drives' Clarendon Press, 1989.

**MAPPING OF CO'S WITH PO'S**

| CO | PO | | | | | |
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| 4 | 3 | - | 3 | - | - | 3 |
| 5 | 3 | 1 | 3 | 3 | 3 | 2 |
| AVG | 2.8 | 1 | 3 | 2.5 | 2.75 | 2.5 |

**22272E16C ADVANCED POWER SYSTEM DYNAMICS** **L T P C**

**OBJECTIVES:** **3 0 0 3**

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

**UNIT ITRANSIENT STABILITY ANALYSIS** **9**

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

**UNIT II UNIFIED ALGORITHM FOR DYNAMIC ANALYSIS OF POWER SYSTEMS 9**

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

**UNIT III SUBSYSNCHRONOUS RESONANCE (SSR) AND OSCILLATIONS 9**

Sub synchronous Resonance (SSR) – Types of SSR - Characteristics of series –Compensated transmission systems –Modeling of turbine-generator-transmission network- Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Methods of analyzing SSR – Numerical examples illustrating instability of subsynchronous oscillations – time-domain simulation of subsynchronous resonance – EMTP with detailed synchronous machine model- Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters

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

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

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

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

- Learners will be able to understand the various schemes available in Transformer protection
- Learners will have knowledge on Over current protection.
- Learners will attain knowledge about Distance and Carrier protection in transmission lines.
- Learners will understand the concepts of Busbar protection.
- Learners will attain basic knowledge on numerical protection techniques

**REFERENCES**


1 R.Ramnujam,” Power System Dynamics Analysis and Simulation”, PHI Learning Private Limited, New Delhi, 2009

2 T.V. Cutsem and C.Vournas, “Voltage Stability of Electric Power Systems”, Kluwer publishers,1998

3 P. Kundur, “Power System Stability and Control”, McGraw-Hill, 1993.

4 H.W. Dommel and N.Sato, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS-91, pp, 1643-1650, July/August 1972.

5 Roderick J . Frowd and J. C. Giri, “Transient stability and Long term dynamics unified”, IEEE Trans., Vol 101, No. 10, October 1982.

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


| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
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| CO1 | 3 | 3 | 3 | 3 | 3 | 1 |
| CO2 | 3 | 3 | 3 | 3 | 3 | 1 |
| CO3 | 3 | 3 | 3 | 3 | 3 | 1 |
| CO4 | 3 | 3 | 3 | 3 | 3 | 1 |
| CO5 | 3 | 3 | 3 | 3 | 3 | 1 |
| AVG | **3** | **3** | **3** | **3** | **3** | **1** |

**22272E16D** **ANALYSIS AND COMPUTATION OF ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS**

**L T P C**

**OBJECTIVES:** **3 0 0 3**

- To understand the various types of transients and its analysis in power system.
- To learn about modeling and computational aspects transients computation

**UNIT I REVIEW OF TRAVELLING WAVE PHENOMENA 9**

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

**UNIT II LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES 9**

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

**UNIT III PARAMETERS AND MODELING OF OVERHEAD LINES 9**

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

**UNIT V FAST TRANSIENTS PHENOMENON IN AIS AND GIS 9**

Digital computation of line parameters: why line parameter evaluation programs? Salient features of a typical line parameter evaluation program; constructional features of that affect transmission line parameters; line parameters for physical and equivalent phase conductors elimination of ground wires bundling of conductors; principle of digital computation of transients: features and capabilities of electromagnetic transients program; steady state and time step solution modules: basic solution methods; case studies on simulation of various types of transients

**TOTAL : 45 PERIODS**

**OUTCOMES:**

- Learners will be able to model over head lines, cables and transformers.
- Learners will be able to analyze power system transients.

**REFERENCES**

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

## MAPPING OF CO'S WITH PO'S

| CO | PO | | | | | |
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| 3 | 3 | 1 | 3 | 2 | 2 | 2 |
| 4 | 3 | - | 3 | - | - | 3 |
| 5 | 3 | 1 | 3 | 3 | 3 | 2 |
| AVG | 2.8 | 1 | 3 | 2.5 | 2.75 | 2.5 |

**22272E24A SMART GRID LTPC**

**3003**

**OBJECTIVES:**

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

**UNIT IINTRODUCTION TO SMART GRID 9**

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

**UNIT II SMART GRID TECHNOLOGIES 9**

Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation ,Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control, Distribution systems: DMS, Volt/Var control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV).

**UNIT III SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9**

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

**UNIT IV POWER QUALITY MANAGEMENT IN SMART GRID 9**

Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

**UNIT V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9**

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

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

**REFERENCES**


1 Stuart Borlase "Smart Grid :Infrastructure, Technology and Solutions", CRC Press 2012.

2 Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley 2012.

3 Vehbi C. Güngör, DilanSahin, TaskinKocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, "Smart Grid Technologies: Communication Technologies and Standards" IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.

4 Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang "Smart Grid – The New and Improved Power Grid: A Survey" , IEEE Transaction on Smart Grids, vol. 14, 2012.


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| AVG | 3 | - | 3 | - | 3 | 3 |

**22272E24B SOLAR AND ENERGY STORAGE SYSTEMS LTPC**

**3003**

**OBJECTIVES:**

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

**UNIT IINTRODUCTION 9**

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

**UNIT II STAND ALONE PV SYSTEM 9**

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

**UNIT III GRID CONNECTED PV SYSTEMS 9**

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

**UNIT IV ENERGY STORAGE SYSTEMS 9**

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

**UNIT V APPLICATIONS 9**

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

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

**REFERENCES**

1 Solanki C.S., "Solar Photovoltaics: Fundamentals, Technologies And Applications", PHI Learning Pvt. Ltd.,2015.

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

3 Frank S. Barnes & Jonah G. Levine, “Large Energy storage Systems Handbook”, CRC Press, 2011.

4 McNeils, Frenkel, Desai, “Solar & Wind Energy Technologies”, Wiley Eastern, 1990

5 S.P. Sukhatme , “Solar Energy”, Tata McGraw Hill,1987.

| CO | PO | | | | | |
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| AVG | 3 | - | 3 | - | 3 | 3 |

**22272E24C POWER SYSTEM RELIABILITY L T P C**

**OBJECTIVES: 3 0 0 3**

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

**UNIT I LOAD FORECASTING 9**

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

**UNIT II GENERATION SYSTEM RELIABILITY ANALYSIS 9**

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

**UNIT III TRANSMISSION SYSTEM RELIABILITY ANALYSIS 9**

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

**UNIT IV EXPANSION PLANNING 9**

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

**UNIT V DISTRIBUTION SYSTEM PLANNING OVERVIEW 9**

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

**TOTAL: 45 PERIODS**

**OUTCOMES:**

- Students will develop the ability to learn about load forecasting.
- Students will learn about reliability analysis of ISO and interconnected systems.
- Students will understand the concepts ot Contingency analysis and Probabilistic Load flow Analysis
- Students will be able to understand the concepts of Expansion planning
- Students will have knowledge on the fundamental concepts of the Distribution system planning

**REFERENCES**


1 Roy Billinton & Ronald N. Allan, "Reliability Evaluation of Power Systems" Springer Publication,

2 R.L. Sullivan, "Power System Planning", Tata McGraw Hill Publishing Company Ltd 1977.

3 X. Wang & J.R. McDonald, "Modern Power System Planning", McGraw Hill Book Company 1994.

4 T. Gonen, "Electrical Power Distribution Engineering", McGraw Hill Book Company 1986.

5 B.R. Gupta, "Generation of Electrical Energy",S.Chand Publications 1983.


**MAPPING OF CO'S WITH PO'S**

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**22272E24D DISTRIBUTED GENERATION AND MICROGRID** **L T P C**

**OBJECTIVES:** **3 0 0 3**

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

**UNIT I INTRODUCTION 9**

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

**UNIT II DISTRIBUTED GENERATIONS (DG) 9**

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

**UNIT III IMPACT OF GRID INTEGRATION 9**

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

**UNIT IV BASICS OF A MICROGRID 9**

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

**UNIT V CONTROL AND OPERATION OF MICROGRID 9**

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

- Learners will attain knowledge on the various schemes of conventional and nonconventional power generation.

- Learners will have knowledge on the topologies and energy sources of distributed generation.
- Learners will learn about the requirements for grid interconnection and its impact with NCE sources
- Learners will understand the fundamental concept of Microgrid.

**REFERENCES**


1 Amirnaser Yezdani, and Reza Iravani, “Voltage Source Converters in Power Systems: Modeling, Control and Applications”, IEEE John Wiley Publications, 2010.

2 DorinNeacsu, “Power Switching Converters: Medium and High Power”, CRC Press, Taylor & Francis, 2006

3 Chetan Singh Solanki, “Solar Photo Voltaics”, PHI learning Pvt. Ltd., New Delhi,2009

4 J.F. Manwell, J.G. McGowan “Wind Energy Explained, theory design and applications”, Wiley publication 2010.

5 D. D. Hall and R. P. Grover, “Biomass Regenerable Energy”, John Wiley, New York, 1987.

6 John Twidell and Tony Weir, “Renewable Energy Resources” Tyalor and Francis Publications, Second edition 2006.


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## 22272E25A - WIND ENERGY CONVERSION SYSTEMS

**3 1 0 4**

**UNIT-I INTRODUCTION**: **9**

History of wind Electric generation - Darrieus wind - Horizontal and vertical axis-Wind turbine - other modern developments - Future possibilities.

**UNIT-II WIND RESOURCE AND ITS POTENTIAL FOR ELECVTRIC POWER GENERATION: 9**

Power Extracted By A Wind Driven Machine - Nature and occurrence of wind characteristics and power production - variation of mean wind speed with time.

**UNIT-III WIND POWER SITES AND WIND MEASUREMENTS**: **9**

Average wind speed and other factors affecting choice of the site - Effect of wind direction - Measurement of wind velocity - Personal estimation without instruments- anemometers - Measurement of wind direction.

**UNIT-IV WIND TURBINES WITH ASYNCHRONOUS GENERATORS AND CONTROL ASPECTS: 9**

Asynchronous systems - Ac Generators - Self excitation of Induction Generator - Single Phase operation of Induction Generator - Permanenet magnet Generators - Basic control aspects - fixed speed ratio control scheme - fixed vs variable speed operation of WECS.

**UNIT-V GENERATION OF ELECTRICITY 9**

Active and reactive power - P and Q transfer in power systems - Power converters - Characteristics of Generators - Variable Speed options - Economics.

**L = 45 T = 15 P = 0 C =4**

**REFERENCES**:

1. N.G.Calvert, 'Wind Power Principles: Their Application on small scale', Charles Friffin& co. Ltd, London, 1979.
2. Gerald W.Koeppel, "Pirnam's and Power from the wind", Van Nastran Reinhold Co., London, 1979.
3. Gary L. Johnson, "Wind Energy System", Prentice hall Inc., Englewood Cliffs, New Jersey, 1985.
4. Wind energy conversion system by L. Lfreris, Prentice hall (U.K) Ltd., 1990.

## MAPPING OF CO'S WITH PO'S

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# 22272E25B - AI TECHNIQUES TO POWER SYSTEMS

**3 1 0 4**

1. **INTRODUCTION TO NEURAL NETWORKS** **9**

   Basics of ANN - perceptron - delta learning rule - back propagation algorithm - multilayer feed forward network - memory models - bi-directional associative memory - Hopfield network.

2. **APPLICATIONS TO POWER SYSTEM PROBLEMS** **9**

   Application of neural networks to load forecasting - contingency analysis - VAR control - economic load dispatch.

3. **INTRODUCTION TO FUZZY LOGIC** **9**

   Crispness - vagueness - fuzziness - uncertainty - fuzzy set theory fuzzy sets - fuzzy set operations - fuzzy measures - fuzzy relations - fuzzy function - structure of fuzzy logic controller – fuzzification models - data base - rule base - inference engine defuzzification module.

4. **APPLICATIONS TO POWER SYSTEMS** **9**

   Decision making in power system control through fuzzy set theory - use of fuzzy set models of LP in power systems scheduling problems - fuzzy logic based power system stabilizer.

5. **GENETIC ALGORITHM AND ITS APPLICATIONS TO POWER SYSTEMS** **9**

   Introduction - simple genetic algorithm - reproduction - crossover - mutation – advanced operators in genetic search - applications to voltage control and stability studies.

**L = 45 T = 15 P = 0 C =4**

**REFERENCES:**


1. James A. Freeman and Skapura.B.M „Neural Networks - Algorithms Applications and Programming Techniques‟, Addison Wesley, 1990.
2. George Klir and Tina Folger.A, „Fuzzy sets, Uncertainty and Information‟, Prentice Hall of India, 1993.
3. Zimmerman.H.J,„Fuzzy Set Theory and its Applications‟, Kluwer Academic Publishers 1994.
4. IEEE tutorial on „Application of Neural Network to Power Systems‟, 1996.
5. Loi Lei Lai, „Intelligent System Applications in Power Engineering‟, John Wiley & SonsLtd.,1998.


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**22272E25C ELECTRICAL DISTRIBUTION SYSTEM L T P C**

**OBJECTIVES: 3 0 0 3**

- To provide knowledge about the distribution system electrical characteristics
- To gain knowledge about planning and designing of distribution system
- To analyze power quality in distribution system
- To analyze the power flow in balanced and unbalanced system

**UNIT I INTRODUCTION 9**

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

**UNIT II DISTRIBUTION SYSTEM PLANNING 9**

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

**UNIT III DISTRIBUTION SYSTEM LINE MODEL 9**

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

**UNIT IV VOLTAGE REGULATION 9**

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

**UNIT V DISTRIBUTION FEEDER ANALYSIS 9**

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

**TOTAL: 45 PERIODS**

**OUTCOMES:**

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

**REFERENCES**

1. William H. Kersting," Distribution System Modeling and Analysis " CRC press 3rd edition,2012.

2. Turan Gonen, "Electric Power Distribution System Engineering", McGraw Hill Company. 1986
3. James Northcote – Green, Robert Wilson, "Control and Automation of Electrical Power Distribution Systems", CRC Press, New York, 2007.
4. Pabla H S, "Electrical Power Distribution Systems", Tata McGraw Hill. 2004

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**22272E25D ENERGY MANAGEMENT AND AUDITING L T P C**

**OBJECTIVES:** **3 0 0 3**

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

**UNIT I INTRODUCTION 9**

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

**UNIT II ENERGY COST ANDLOAD MANAGEMENT 9**

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

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

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

**UNIT IV METERING FOR ENERGY MANAGEMENT 9**

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

**UNIT V LIGHTING SYSTEMS & COGENERATION 9**

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

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

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

**REFERENCES**


1 Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, "Guide to Energy Management", Fifth Edition, The Fairmont Press, Inc., 2006

2 Eastop T.D & Croft D.R, "Energy Efficiency for Engineers and Technologists", Logman Scientific & Technical, 1990.

3 Reay D.A, "Industrial Energy Conservation", 1st edition, Pergamon Press, 1977.

4 "IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities", IEEE, 1996

5 Amit K. Tyagi, "Handbook on Energy Audits and Management", TERI, 2003.


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| AVG | **3** | **3** | **3** | **3** | **3** | **1** |

## 22272E32A - POWER ELECTRONICS APPLICATIONS IN POWER SYSTEMS

**3 1 0 4**

**UNIT: I STATIC COMPENSATOR CONTROL 9**

Theory of load compensation - voltage regulation and power factor correction - phase balance and PF correction of unsymmetrical loads - Property of static compensator - Thyristor controlled rectifier (TCR) - Thyristor Controlled Capacitor (TSC) -Saturable core reactor - Control Strategies.

**UNIT: II HARMONIC CONTROL AND POWER FACTOR IMPROVEMENT 9**

Input power factor for different types of converters - power factor improvement using Load and forced commutated converters.

**UNIT: III VOLTAGE CONTROL USING STATIC TAP-CHANGERS 9**

Conventional tap changing methods, static tap changers using Thyristor, different schemes - comparison.

**UNIT: IV STATIC EXCITATION CONTROL 9**

Solid state excitation of synchronous generators - Different schemes - Generex excitation systems.

**UNIT: V UNINTERRUPTABLE POWER SUPPLY SYSTEM 9**

Parallel, Redundant and non- redundant UPS - Ups using resonant power converters - Switch mode power supplies.

**L = 45 T = 15 P = 0 C =4**

**TEXT BOOK**

Miller. T.J.E, “Reactive power control in Electric systems”. Wiley inter science, New York, 1982.

**REFRENCES**

1. “Static Compensator for AC power systems”, Proc. IEE vol.128 Nov. 1981. pp 362-406.
2 “A Static alternative to the transformer on load tap changing”, IEEE Trans. On Pas, Vol.PAS-99, Jan. /Feb. 1980, pp86-89.
3. “Improvements in Thyristor controlled static on- load tap controllers for transformers”, IEEE Trans. on PAS, Vol.PAS-101, Sept.1982, pp3091-3095.
4. “Shunt Thyristor rectifiers for the Generex Excitation systems”, IEEE Trans. On PAS. PAS -96, July/August, 1977, pp1219-1325.

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| AVG | **3** | **3** | **3** | **3** | **3** | **1** |

# 22272E32B- POWER SYSTEM DYNAMICS

**3 1 0 4**

## 1. SYNCHRONOUS MACHINE MODELLING 9

Schematic Diagram, Physical Description: armature and field structure, machines with multiple pole pairs, mmf waveforms, direct and quadrature axes, Mathematical Description of a Synchronous Machine: Basic equations of a synchronous machine: stator circuit equations, stator self, stator mutual and stator to rotor mutual inductances, dq0 Transformation: flux linkage and voltage equations for stator and rotor in dq0 coordinates, electrical power and torque, physical interpretation of dq0 transformation, Per Unit Representations: $L_{ad}$-reciprocal per unit system and that from power-invariant form of Park's transformation; Equivalent Circuits for direct and quadrature axes, Steady-state Analysis: Voltage, current and flux-linkage relationships, Phasor representation, Rotor angle, Steady-state equivalent circuit, Computation of steady-state values, Equations of Motion: Swing Equation, calculation of inertia constant, Representation in system studies, Synchronous Machine Representation in Stability Studies: Simplifications for large-scale studies : Neglect of stator $p\Psi$ terms and speed variations, Simplified model with amortisseurs neglected: two-axis model with amortisseur windings neglected, classical model.

## 2. MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS 9

Excitation System Requirements; Elements of an Excitation System; Types of Excitation System;Control and protective functions;IEEE (1992) block diagram for simulation of excitation systems. Turbine and Governing System Modelling: Functional Block Diagram of Power Generation and Control, Schematic of a hydroelectric plant, classical transfer function of a hydraulic turbine (no derivation), special characteristic of hydraulic turbine, electrical analogue of hydraulic turbine, Governor for Hydraulic Turbine: Requirement for a transient droop, Block diagram of governor with transient droop compensation, Steam turbine modelling: Single reheat tandem compounded type only and IEEE block diagram for dynamic simulation; generic speed-governing system model for normal speed/load control function.

## 3. SMALL-SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS 9

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

## 4. SMALL-SIGNAL STABILITY ANALYSIS WITH CONTROLLERS 9

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

**5. ENHANCEMENT OF SMALL SIGNAL STABILITY 9**

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

**L = 45 T = 15 P = 0 C =4**

**REFERENCES**


1. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
2. IEEE Committee Report, "Dynamic Models for Steam and Hydro Turbines in Power System Studies", IEEE Trans., Vol.PAS-92, pp 1904-1915, November/December, 1973. on Turbine-Governor Model.
3. P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press, Ames, Iowa, 1978
4. .


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**22272E32C** **ELECTRIC VEHICLES AND POWER MANAGEMENTL** **T P C**

**3 0 0 3**

**OBJECTIVES:**

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

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

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

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

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

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

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

**UNIT IV BATTERY ENERGY STORAGE SYSTEM 9**

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

**UNIT V ALTERNATIVE ENERGY STORAGE SYSTEMS 9**

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

- Learners will understand the operation of Electric vehicles and various energy storage technologies for electrical vehicles

**REFERENCES**


**1** Iqbal Hussain, "**Electric and Hybrid Vehicles: Design Fundamentals, Second Edition"** CRC Press, Taylor & Francis Group, Second Edition (2011).

**2** Ali Emadi, Mehrdad Ehsani, John M.Miller, "Vehicular Electric Power Systems", Special Indian Edition, Marcel dekker, Inc 2010.


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| 22272E32D | ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY | L | T | P | C |
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**OBJECTIVES:**

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

**UNIT I INTRODUCTION 9**

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

**UNIT II GROUNDING AND CABLING 9**

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

**UNIT III BALANCING, FILTERING AND SHIELDING 9**

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

**UNIT IVEMI IN ELEMENTS AND CIRCUITS 9**

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

**UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES 9**

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

**TOTAL: 45 PERIODS**

**OUTCOMES:**

- Recognize the sources of Conducted and radiated EMI in Power Electronic Converters and consumer appliances and suggest remedial measures to mitigate the problems
- Assess the insertion loss and design EMI filters to reduce the loss
- Design EMI filters, common-mode chokes and RC-snubber circuits measures to keep the interference within tolerable limits

**REFERENCES**


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


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***ELECTIVES – V (semester-III)***

## 22272E33A - POWER CONDITIONING

**3 1 0 4**

### 1. INTRODUCTION 9

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

### 2. NON-LINEAR LOADS 9

Single phase static and rotating AC/DC converters, Three phase static AC/DC converters, Battery chargers, Arc furnaces, Fluorescent lighting, pulse modulated devices, Adjustable speed drives.

### 3. MEASUREMENT AND ANALYSIS METHODS 9

Voltage, Current, Power and Energy measurements, power factor measurements and definitions, event recorders, Measurement Error – Analysis: Analysis in the periodic steady state, Time domain methods, Frequency domain methods: Laplace′s, Fourier and Hartley transform – The Walsh Transform – Wavelet Transform.

### 4. ANALYSIS AND CONVENTIONAL MITIGATION METHODS 9

Analysis of power outages, Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers, Analysis of distortion: On–line extraction of fundamental sequence components from measured samples – Harmonic indices – Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI)- Analysis of voltage flicker, Reduced duration and customer impact of outages, Classical load balancing problem: Open loop balancing, Closed loop balancing, current balancing, Harmonic reduction, Voltage sag reduction.

### 5. POWER QUALITY IMPROVEMENT 9

Utility-Customer interface –Harmonic filters: passive, Active and hybrid filters –Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM, Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC –control strategies: P- Q theory, Synchronous detection method – Custom power park –Status of application of custom power devices

**L = 45 T = 15 P = 0 C =4**

**REFERENCES:**

1. Arindam Ghosh “Power Quality Enhancement Using Custom Power Devices”, Kluwer Academic Publishers, 2002.
2. Heydt.G.T, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition)
3. Dugan.R.C, “ Electrical Power System Quality”,TMH,2008.
4. Arrillga.A.J and Neville R.Watson, Power System Harmonics, John Wiley second Edition,2003.
5. Derek A. Paice, “Power electronic converter harmonics”,John Wiley & sons, 1999.

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6.

***ELECTIVES – V (semester-III)***

## 22272E33B – DEREGULATED POWER SYSTEM

**3 1 0 4**

**COURSE OBJECTIVES;**

Students will be able to:

- Describe the behavior of deregulated markets in power system.
- Describe the technical and non-technical issues in deregulated power industry.
- Identify the methods of Local Marginal prices calculation in transmission and the function of financial transmission rights.
- Analyze the energy and ancillary services management in deregulated power industry.
- Discriminate the restructuring framework US and Indian power sectors

**1. FUNDAMENTALS AND ARCHITECTURE OF POWERMARKETS 9**

Deregulation of Electric utilities: Introduction-Unbundling-Wheeling- Reform motivations- Fundamentals of Deregulated Markets – Types (Future, Day-ahead and Spot) – Participating in Markets (Consumer and Producer Perspective) – bilateral markets – pool markets. Independent System Operator (ISO)-components-types of ISO - role of ISO - Lessons and Operating Experiences of Deregulated Electricity Markets in various Countries (UK, Australia, Europe, US, Asia).

**2. TECHNICAL CHALLENGES 9**

Total Transfer Capability – Limitations - Margins – Available transfer capability (ATC) – Procedure - Methods to compute ATC – Static and Dynamic ATC – Effect of contingency analysis – Case Study. Concept of Congestion Management – Bid, Zonal and Node Congestion Principles – Inter and Intra zonal congestion – Generation Rescheduling - Transmission congestion contracts – Case Study.

**3. TRANSMISSION NETWORKS AND SYSTEM SECURITY SERVICES 9**

Transmission expansion in the New Environment – Introduction – Role of transmission planning – Physical Transmission Rights – Limitations – Flow gate - Financial Transmission Rights – Losses – Managing Transmission Risks – Hedging – Investment. Ancillary Services – Introduction – Describing Needs – Compulsory and Demand-side provision – Buying and Selling Ancillary Services – Standards.

**4. MARKET PRICING 9**

Transmission pricing in open access system – Introduction – Spot Pricing – Uniform Pricing – Zonal Pricing – Locational Marginal Pricing – Congestion Pricing – Ramping and Opportunity Costs. Embedded cost based transmission pricing methods (Postage stamp, Contract path and MW-mile) – Incremental cost based transmission pricing methods ( Short run marginal cost, Long run marginal cost) - Pricing of Losses on Lines and Nodes.

**INDIAN POWER MARKET 9**

Current Scenario – Regions – Restructuring Choices – Statewise Operating Strategies – Salient features of Indian Electricity Act 2003 – Transmission System

Operator – Regulatory and Policy development in Indian power Sector – Opportunities for IPP and Capacity Power Producer. Availability based tariff – Necessity – Working Mechanism – Beneficiaries – Day Scheduling Process – Deviation from Schedule – Unscheduled Interchange Rate – System Marginal Rate – Trading Surplus Generation – Applications.

**L = 45 T = 15 P = 0 C =4**

**COURSE OUTCOMES:**

Students will be able to:

**CO1:** Describe the requirement for deregulation of the electricity market and the principles of market models in power systems.

**CO2:** Analyze the methods of congestion management in deregulated power system

**CO3:** Analyze the locational marginal pricing and financial transmission rights

**CO4:** Analyze the ancillary services management

**CO5:** Differentiate the framework of US and Indian power sectors

**REFERENCES**

1. Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder, "Operation of Restructured Power Systems", Kluwer Academic Publishers, 2001



2. Loi Lei Lai, "Power system Restructuring and Regulation", John Wiley sons, 2001.

3. Shahidehpour.M and Alomoush.M, "Restructuring Electrical Power Systems", Marcel Decker Inc., 2001.

4. Steven Stoft, " Power System Economics", Wiley – IEEE Press, 2002

5. Daniel S. Kirschen and Goran Strbac, " Fundamentals of Power System Economics", John Wiley & Sons Ltd., 2004.

6. Scholarly Transaction Papers and Utility web sites

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| 22272E33C | CONTROL SYSTEM DESIGN FOR POWER ELECTRONICS | L | T | P | C |
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**OBJECTIVES:**

- To explore conceptual bridges between the fields of Control Systems and Power Electronics
- To Study Control theories and techniques relevant to the design of feedback controllers in Power Electronics.

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

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

**UNIT II SLIDING MODE CONTROLLER DESIGN 9**

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

**UNIT III APPROXIMATE LINEARIZATION CONTROLLER DESIGN 9**

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

**UNIT IV NONLINEAR CONTROLLER DESIGN 9**

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

**UNIT V PREDICTIVE CONTROL OF POWER CONVERTERS 9**

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

**TOTAL:45 PERIODS**

**OUTCOMES:**

- Ability to understand an overview on modern linear and nonlinear control strategies for power electronics devices
- Ability to model modern power electronic converters for industrial applications
- Ability to design appropriate controllers for modern power electronics devices.

**REFERENCES**


**1.** Hebertt Sira-Ramírez, Ramón Silva-Ortigoza, "Control Design Techniques in Power Electronics Devices", Springer 2012

**2.** Mahesh Patil, Pankaj Rodey, "Control Systems for Power Electronics: A Practical Guide", Springer India, 2015.

**3.** Blaabjerg José Rodríguez, "Advanced and Intelligent Control in Power Electronics and Drives" , Springer, 2014

**4.** Enrique Acha, Vassilios Agelidis, Olimpo Anaya, TJE Miller, "Power Electronic Control in Electrical Systems", Newnes, 2002

**5.** Marija D. Aranya Chakrabortty, Marija , "Control and Optimization Methods for Electric Smart Grids", Springer, 2012.

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| AVG | 2.8 | 2 | 2.8 | 3 | 2.5 | 2.5 |

**22272E33D PRINCIPLES OF EHV TRANSMISSION L T P C**
**3 0 0 3**

**OBJECTIVES:**

To impart knowledge on,

- Types of power transmission and configurations various parameters and voltage gradients of transmission line conductors.
- The design requirements of EHV AC and DC lines.

**UNIT I INTRODUCTION 9**

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

**UNIT II CALCULATION OF LINE PARAMETERS 9**

Calculation of resistance, inductance and capacitance for multi-conductor lines – calculation of sequence inductances and capacitances – line parameters for different modes of propagation – effect of ground return.

**UNIT III VOLTAGE GRADIENTS OF CONDUCTORS 9**

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

**UNIT IV ELECTROSTATIC FIELD AND DESIGN OF EHV LINES 9**

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

**UNIT V HVDC LINES**

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

- Ability to model the transmission lines and estimate the voltage gradients and losses
- Ability to design EHV AC and DC transmission lines

**REFERENCES**

1 Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, Second Edition, New Age International Pvt. Ltd., 2006.
2 Pritindra Chowdhari, “Electromagnetic transients in Power System”, John Wiley and Sons Inc., 2009.
3 Sunil S.Rao, “EHV-AC, HVDC Transmission & Distribution Engineering”, Third Edition, Khanna Publishers, 2008.
4 William H. Bailey, Deborah E. Weil and James R. Stewart, “A Review on HVDC Power Transmission Environmental Issues”, Oak Ridge National Laboratory.
5 J.C Molburg, J.A. Kavicky, and K.C. Picel ,”A report on The design, Construction and operation of Long-distance High-Voltage Electricity Transmission Technologies” Argonne (National Laboratory) 2007.
6 “Power Engineer’s Handbook”, Revised and Enlarged 6th Edition, TNEB Engineers’ Association, October 2002.

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***ELECTIVES – VI (semester-III)***

# 22272E34A - SOFTWARE FOR CONTROL SYSTEM DESIGN

**3 1 0 4**

## 1. INTRODUCTION TO DESIGN AND CLASSICAL PID CONTROL

Systems performance and specifications –Proportional, Integral and Derivative Controllers – Structure – Empirical tuning- Zeigler Nichols-Cohen Coon – Root Locus method – Open loop inversion-– Tuning using ISE, IAE and other performance indices.

## 2. COMPENSATOR DESIGN

Design of lag, lead, lead-lag compensators – Design using bode plots – Polar plots – Nichols charts – root locus and Routh Hurwitz criterion.

## 3. MATLAB

Introduction – function description – Data types – Tool boxes – Graphical Displays – Programs for solution of state equations – Controller design – Limitations.- simulink-Introduction – Graphical user interface – Starting – Selection of objects – Blocks – Lines - simulation – Application programs – Limitations.

## 4. MAPLE

Introduction – symbolic programming – Programming constructs – Data structure computation with formulae – Procedures – Numerical Programming.

## 5. MATLAB

Programs using MATLAB software

**L = 45 T = 15 P = 0 C =4**

## REFERENCES

1. MAPLE V Programming guide.
2. MATLAB user manual.
3. SIMULINK user manual.
4. K.Ogatta ,"Modern Control Engineering",PHI,1997.
5. Dorf and Bishop,"Modern control Engineering', Addison Wesley, 1998.

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**22272E34B - INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN**

**3 1 0 4**

**1. MOTOR STARTING STUDIES 9**

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

**2. POWER FACTOR CORRECTION STUDIES 9**

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

**3. HARMONIC ANALYSIS 9**

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

**4. FLICKER ANALYSIS 9**

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

**5. GROUND GRID ANALYSIS 9**

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

**L = 45 T = 15 P = 0 C =4**

**REFERENCES**

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

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| AVG | 2.8 | 2 | 2.8 | 3 | 2.5 | 2.5 |

**22272E34C SOFT COMPUTING TECHNIQUES L T P C**

M.Tech, (Power System- R2022) FULL TIME

**OBJECTIVES: 3 0 0 3**

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

**UNIT I INTRODUCTION AND ARTIFICIAL NEURAL NETWORKS 9**

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

**UNIT II ARTIFICIAL NEURAL NETWORKS AND ASSOCIATIVE MEMORY 9**

Counter propagation network- architecture- functioning & characteristics of counter Propagation network- Hopfield/ Recurrent network configuration - stability constraints associative memory and characteristics- limitations and applications- Hopfield v/s Boltzman machine- Adaptive Resonance Theory- Architecture- classifications- Implementation and training - Associative Memory.

**UNIT III FUZZY LOGIC SYSTEM 9**

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

**UNIT IV GENETIC ALGORITHM 9**

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

**UNIT V HYBRID CONTROL SCHEMES 9**

Fuzzification and rule base using ANN–Neuro fuzzy systems-ANFIS – Fuzzy

Neuron - Optimization of membership function and rule base using Genetic



Algorithm –Introduction to Support Vector Machine - Evolutionary Programming-Particle Swarm Optimization - Case study – Familiarization of NN, FLC and ANFIS Tool Box.

**TOTAL : 45 PERIODS**

**OUTCOMES:**

- Will be able to know the basic ANN architectures, algorithms and their limitations.
- Also will be able to know the different operations on the fuzzy sets.
- Will be capable of developing ANN based models and control schemes for non-linear system.
- Will get expertise in the use of different ANN structures and online training algorithm.
- Will be knowledgeable to use Fuzzy logic for modeling and control of non-linear systems.
- Will be competent to use hybrid control schemes and P.S.O and support vector Regressive.

**TEXT BOOKS:**

1. Laurene V. Fausett, “Fundamentals of Neural Networks: Architectures, Algorithms And Applications”, Pearson Education.
2. Timothy J. Ross, “Fuzzy Logic with Engineering Applications” Wiley India, 2008.
3. Zimmermann H.J. "Fuzzy set theory and its Applications" Springer international edition, 2011.
4. David E.Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Pearson Education, 2009.
5. W.T.Miller, R.S.Sutton and P.J.Webrose, “Neural Networks for Control” MIT Press”, 1996.
6. T. Ross, “Fuzzy Logic with Engineering Applications”, Tata McGraw Hill, New Delhi, 1995.
7. Ethem Alpaydin, “Introduction to Machine Learning (Adaptive Computation and Machine Learning Series)”, MIT Press, 2004.
8. Corinna Cortes and V. Vapnik, " Support - Vector Networks, Machine Learning ” 1995.

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9.

**22272E34D RESTRUCTURED POWER SYSTEM LTPC**
**OBJECTIVES: 3003**



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

**UNIT I INTRODUCTION TO RESTRUCTURING OF POWER INDUSTRY 9**

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

**UNIT II TRANSMISSION CONGESTION MANAGEMENT 9**

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

**UNIT III LOCATIONAL MARGINAL PRICES AND FINANCIAL TRANSMISSION RIGHTS 9**

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

**UNIT IV ANCILLARY SERVICE MANAGEMENT AND PRICING OF TRANSMISSION NETWORK 9**

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

**UNIT V REFORMS IN INDIAN POWER SECTOR 9**

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

**TOTAL : 45 PERIODS**

**OUTCOMES:**

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

**REFERENCES**


1 Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker, “Restructured electrical power systems: operation, trading and volatility” Pub., 2001.

2 Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen, “Operation of restructured power systems”, Kluwer Academic Pub., 2001.

3 Paranjothi, S.R. , “Modern Power Systems” Paranjothi, S.R. , New Age International, 2017.

4 Sally Hunt,” Making competition work in electricity”, John Willey and Sons Inc. 2002.

5 Steven Stoft, “Power system economics: designing markets for electricity”, John Wiley & Sons, 2002.


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