# PRIST
# DEEMED TO BE UNIVERSITY

**VALLAM, THANJAVUR.**

## *DEPARTMENT OF EEE*

## M.TECH-POWER SYSTEMS (FULL TIME)

## COURSE STRUCTURE -R2017

**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 level higher than the requirements in the appropriate bachelor program

**PO 4:** Ability to attain professional ethics and intellectual integrity to contribute to the community for sustainable development of society

**PO 5:** Apply knowledge of basic science and engineering in analysis and modeling of the power system components

**PO 6**: Implement cost effective and cutting edge technologies in Power System

**PROGRAMME EDUCATIONAL OBJECTIVES**:

**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-today operation and planning of Power System.

**PEO 3:** To develop the ability to design various controllers to enhance the stability and power transfer 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, design and investigation of modern electric power systems.

# PRIST DEEMED TO BE UNIVERSITY

## FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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

**CURRICULUM -REGULATION 2017**

**SEMESTER – I**

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1. | 17248S11D | Applied Mathematics For Electrical &Electronics Engineering | 3 | 1 | 0 | 4 |
| 2 | 17272H12 | System Theory | 3 | 1 | 0 | 4 |
| 3 | 17272H13 | Power System Modeling and Analysis | 3 | 1 | 0 | 4 |
| 4 | 17272H14 | Economic Operations of Power Systems-I | 3 | 1 | 0 | 4 |
| 5 | 17272H15 | High Voltage Direct Current Transmission System | 3 | 1 | 0 | 4 |
| 6 | 17272E16_ | Elective-I | 3 | 1 | 0 | 4 |
| 7 | 17272L17 | Power System Simulation Lab-I | 0 | 0 | 3 | 3 |
| 8 | 17272CRS | Research Led Seminar | | | | 1 |
| | | TOTAL | | | | 28 |

**SEMESTER – II**

| SL. NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272H21 | EHV power transmission | 3 | 1 | 0 | 4 |
| 2 | 17272H22 | Economic Operations of Power Systems-II | 3 | 1 | 0 | 4 |
| 3 | 17272H23 | Power System Protection | 3 | 1 | 0 | 4 |
| 4 | 17272E24_ | Elective –II | 3 | 1 | 0 | 4 |
| 5 | 17272E25_ | Elective –III | 3 | 1 | 0 | 4 |
| 6 | 17272L26 | Power System Simulation Lab-II | 0 | 0 | 3 | 3 |
| 7 | 172TECWR | Technical Writing/Seminars | 0 | 0 | 3 | 3 |
| 8 | 17272CRM | Research Methodology | | | | 3 |
| 9 | 17272CBR | Participation in Bounded Research | | | | 2 |
| | | TOTAL | | | | 31 |

## SEMESTER – III

| SL. NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272H31 | Electrical Transients in power systems | 3 | 1 | 0 | 4 |
| 2 | 17272E32_ | Elective –IV | 3 | 1 | 0 | 4 |
| 3 | 17272E33_ | Elective –V | 3 | 1 | 0 | 4 |
| 4 | 17272E34_ | Elective –VI | 3 | 1 | 0 | 4 |
| 5 | 17272P35 | Project work Phase-I | 0 | 0 | 6 | 6 |
| 6 | 17272CSR | Design Project / Socio Technical Project (Scaffolded Research) | | | | 4 |
| | | TOTAL | | | | 26 |

## SEMESTER – IV

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272P44 | Project work Phase-II | 0 | 0 | 12 | 12 |

**Total Credits = 97**

## Elective –I

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272E16A | Analysis of Inverters | 3 | 1 | 0 | 4 |
| 2. | 17272E16B | Modeling and Analysis of Electrical Machines | 3 | 1 | 0 | 4 |

## Elective –II

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272E24A | Flexible AC Transmission system | 3 | 1 | 0 | 4 |
| 2. | 17272E24B | Power System Planning and Reliability | 3 | 1 | 0 | 4 |

## Elective –III

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272E25A | Wind Energy conversion systems | 3 | 1 | 0 | 4 |
| 2. | 17272E25B | AI Techniques to Power Systems | 3 | 1 | 0 | 4 |

**Elective –IV**

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272E32A | Power Electronics applications in Power systems | 3 | 1 | 0 | 4 |
| 2. | 17272E32B | Power system Dynamics | 3 | 1 | 0 | 4 |

**Elective –V**

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272E33A | Power Conditioning | 3 | 1 | 0 | 4 |
| 2. | 17272E33B | Power system restructuring and deregulation | 3 | 1 | 0 | 4 |

**Elective –VI**

| SL.NO. | SUBJECT CODE | SUBJECT | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | 17272E34A | Software for Control system Design | 3 | 1 | 0 | 4 |
| 2. | 17272E34B | Industrial Power system analysis and design | 3 | 1 | 0 | 4 |

# 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** |

# ***SYLLABUS***

*SEMESTER I*

**17248S11D - APPLIED MATHEMATICS FOR ELECTRICAL &ELECTRONICS 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 |

***SEMESTER – I***

# 17272H12 - 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 |

***SEMESTER – I***

# 17272H13 - POWER SYSTEM MODELLING AND ANALYSIS

**3 1 0 4**

## 1. SOLUTION TECHNIQUE 9

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

## 2. 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; Net Interchange power control in Multi-area power flow analysis: ATC, Assessment of Available Transfer Capability (ATC) using Repeated Power Flow method; Continuation Power Flow method.

## 3. 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.

## 4. SHORT CIRCUIT ANALYSIS 9

Fault calculations using sequence networks for different types of faults. Bus impedance matrix (ZBUS) construction using Building Algorithm for lines with mutual coupling; Simple numerical problems. 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 domain using Thevenin's equivalent and ZBUS matrix for different faults.

## 5. 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***

## REFERENCES:

1. G W Stagg, A.H El. Abiad "Computer Methods in Power System Analysis", McGraw Hill 1968.
2. P.Kundur, "Power System Stability and Control", McGraw Hill, 1994.
3. A.J.Wood and B.F.Wollenberg, "Power Generation Operation and Control", John Wiley and sons, New York, 1996.
4. W.F.Tinney and W.S.Meyer, "Solution of Large Sparse System by Ordered Triangular Factorization" IEEE Trans. on Automatic Control, Vol: AC-18, pp: 333-346, Aug 1973.
5. K.Zollenkopf, "Bi-Factorization: Basic Computational Algorithm and Programming Techniques; pp: 75-96; Book on "Large Sparse Set of Linear Systems" Editor: J.K.Rerd,Academic Press, 1971.

*SEMESTER - I*

# 17272H14 - ECONOMIC OPERATIONS OF POWER SYSTEMS-I

**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 |

***SEMESTER – I***

## 17272H15- HIGH VOLTAGE DIRECT CURRENT TRANSMISSION SYSTEM

**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.

**1. DC POWER TRANSMISSION TECHNOLOGY 9**

Introduction – comparison of Ac and DC transmission _ application of DC transmission – description of DC transmission system system – planning for HVDC transmission – modern trends in DC transmission.

**2. ANALYSIS OF HVDC CONVERTERS 9**

Pulse number – choice of converter configuration simplified analysis of Graetz circuit converter converter bridge characteristics – characteristics of a twelve pulse converter – detailed analysis of converters.

**3. CONVERTER AND HVDC SYSTEM CONTROL 9**

General principles of DC link control – converter control characteristics – systems control hierarchy – firing angle control – current and extinction angle control – starting and stopping of DC link – power control – higher level controllers – telecommunication requirements.

**4. HARMONICS AND FILTERS 9**

Introduction – generation of harmonics – design of AC filters – DC filters – carrier frequency and RI noise.

**5. SIMULATION OF HVDC SYSTEMS 9**

Introduction – system simulation: Philosophy and tools- HVDC system simulation – modeling of HVDC systems for digital dynamic simulation.

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

**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. Padiyar. K.R., HVDC power transmission system, Wiley Eastern Limited, New Delhi, 1990.
2. Edward Wilson Kimbark, Direct Current Transmission, Vol.1, Wiley Interscience, New York, London, Sydney, 1971.
3. Rakosh Das Begamudre, Extra high voltage AC transmission engineering Wiley Eastern Ltd., New Delhi, 1990.
4. Arrillaga, J, High voltage direct current transmission, peter Pregrinus, London, 1983.
5. Adamson.C and Hingorani.N.G., High Voltage Direct Current Power Transmission, Garraway Limited, London, 1960. WWW.hvdc.ca

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

| CO | PO | | | | | |
|---|---|---|---|---|---|---|
| | 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 |

**17272L17- POWER SYSTEM SIMULATION LABORATORY – I 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
-

**EXPERIMENTS**

1. Formation of Y bus, Z bus, line parameters and modeling of transmission lines.
2. Power flow analysis: Gauss – Seidel Method.
3. Power flow analysis: Newton Raphson method.
4. Plain Decoupled and Fast Decoupled methods.
5. Contingency analysis – single and multiple symmetrical and unsymmetrical faults.

**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 |

# 17272H21 - 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** |

***SEMESTER – II***

# 17272H22 - ECONOMIC OPERATIONS OF POWER SYSTEMS-II

**3 1 0 4**

## 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**

**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.

## 17272H23 - POWER SYSTEM PROTECTION

**3 1 0 4**

**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. INTRODUCTION 9

General philosophy – Review of conventional equipment protection schemes – state of the art: Numerical relays

### 2. DISTANCE PROTECTION 9

Transmission line protection – fault clearing times – relaying quantities during swings – evaluation of distance relay performance during swings – prevention of tripping during transient conditions – automatic line reclosing – generator out of step protection – simulation of distance relays during transients.

### 3. GENERATOR PROTECTION 9

Out – of – step, loss of excitation. System response to severe upsets – nature of system response to severe upsets – frequency actuated schemes for load shedding and islanding.

### 4. INTRODUCTION TO COMPUTER RELAYING 9

Development of computer relaying – historical background – Expected benefits of computer relaying – computer relay architecture – A/D converter – Anti aliasing filters – substation computer hierarchy.

### 5. DIGITAL TRANSMISSION LINE RELAYING 9

Introduction – source of error – relaying as parameter estimation – beyond parameter estimation – symmetrical component distance relay – protection of series compensated lines. Digital protection of transformers, machines and buses.

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

**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. Arun k. Phadke, James.S.Thorp, " Computer relaying for power system", John Wiley and sons, New York, 1988.
2. Jones D., "Analysis and protection of electrical power systems", Pitman Publishing, 1971.
3. "Power system references manual, Ray rolls protection", Orient press, 1982.
4. Stanly H., Horowitz ( ED), "Protective relaying for power system", IEEE press, 1980.
5. Kundur P., "power system stability and control", McGraw Hill, 1994.


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

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

***SEMESTER - II***

**17272L26- POWER SYSTEM SIMULATION LAB – II 0 0 3 3**

**LIST OF EXPRIMENTS:**

1. Small signal stability analysis: SMIB and Multi machine configuration.
2. Transients stability analysis of Multi – machine configuration.
3. Load Frequency control: single area, multi area control.
4. Economic load dispatch with losses
5. Unit commitment by dynamic programming & priority list method

**P=3 C=3**

***SEMESTER – III***

## 17272H31 - 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

***ELECTIVE- I (semester-I)***

# 17272E16A - ANALYSIS OF INVERTERS

**3 1 0 4**

**UNIT- I- SINGLE PHASE INVERTERS 9**

Introduction to self commutated switches: MOSFET and IGBT - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – various harmonic elimination techniques – forced commutated Thyristor inverters.

**UNIT-II- THREE PHASE VOLTAGE SOURCE INVERTERS 9**

180 degree and 120 degree conduction mode inverters with star and delta connected loads – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques.

**UNIT-III- CURRENT SOURCE INVERTERS 9**

Operation of six-step thyristor inverter – inverter operation modes – load – commutated inverters – Auto sequential current source inverter (ASCI) – current pulsations – comparison of current source inverter and voltage source inverters

**UNIT-IV- MULTILEVEL INVERTERS 9**

Multilevel concept – diode clamped – flying capacitor – cascade type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters

**UNIT-V- RESONANT INVERTERS 9**

Series and parallel resonant inverters - voltage control of resonant inverters – Class E resonant inverter – resonant DC – link inverters.

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

**TEXT BOOKS**

1. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hall India, Third Edition, New Delhi, 2004.
2. Jai P.Agrawal, “Power Electronics Systems”, Pearson Education, Second Edition, 2002.
3. Bimal K.Bose “Modern Power Electronics and AC Drives”, Pearson Education, Second Edition, 2003.

4. Ned Mohan,Undeland and Robbin, “Power Electronics: converters, Application and design” John Wiley and sons.Inc,Newyork,1995.
5. Philip T. krein, “Elements of Power Electronics” Oxford University Press -1998.

**REFERENCES**

1. P.C. Sen, “Modern Power Electronics”, Wheeler Publishing Co, First Edition, New Delhi, 1998.
2. P.S.Bimbra, “Power Electronics”, Khanna Publishers, Eleventh Edition, 2003.

## 17272E16B - 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.
.

**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.

**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 |

***ELECTIVES – II (semester-II)***

## 17272E24A - FLEXIBLE AC TRANSMISSION SYSTEM

**3 1 0 4**

### 1. INTRODUCTION 9

FACTS-a toolkit, Basic concepts of Static VAR compensator, Resonance damper, Thyristor controlled series capacitor, Static condenser, Phase angle regulator, and other controllers.

### 2. SERIES COMPENSATION SCHEMES 9

Sub-Synchronous resonance, Torsional interaction, torsional torque, Compensation of conventional, ASC, NGH damping schemes, Modelling and control of thyristor controlled series compensators.

### 3. UNIFIED POWER FLOW CONTROL 9

Introduction, Implementation of power flow control using conventional thyristors, Unified power flow concept, Implementation of unified power flow controller.

### 4. DESIGN OF FACTS CONTROLLERS 9

Approximate multi-model decomposition, Variable structure FACTS controllers for Power system transient stability, Non-linear variable-structure control, variable structure series capacitor control, variable structure resistor control.

### 5. STATIC VAR COMPENSATION 9

Basic concepts, Thyristor controlled reactor (TCR), Thyristors switched reactor(TSR), Thyristor switched capacitor(TSC), saturated reactor (SR) , and fixed capacitor (FC)

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

### REFERENCES


1. Narin G.Hingorani, " Flexible AC Transmission ", IEEE Spectrum, April 1993, pp 40-45.
2. Narin G. Hingorani, " High Power Electronics and Flexible AC Transmission Systems ", IEEE Power Engineering Review, 1998.
3. Narin G.Hingorani, " Power Electronics in Electric Utilities : Role of Power Electronics in future power systems ", Proc. of IEEE, Vol.76, no.4, April 1988.
4. Einar V.Larsen, Juan J. Sanchez-Gasca, Joe H.Chow, " Concepts for design of FACTS Controllers to damp power swings ", IEEE Trans On Power Systems, Vol.10, No.2, May 1995.
5. Gyugyi L., " Unified power flow control concept for flexible AC transmission ", IEEE Proc-C Vol.139, No.4, July 1992.


### 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 |

## 17272E24B - POWER SYSTEM PLANNING AND RELIABILITY

**3 1 0 4**

### 1. 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.

### 2. 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.

### 3. 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.

### 4. 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.

### 5. 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.

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

### REFERENCES

1. Proceeding of work shop on energy systems planning & manufacturing CI.
2. R.L .Sullivan, " Power System Planning",.
3. Roy Billinton and Allan Ronald, "Power System Reliability."
4. Turan Gonen, Electric power distribution system Engineering 'McGraw Hill,1986

### 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 |

# 17272E25A - 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.

## 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 |

*ELECTIVE III* ***(semester-II)***

# 17272E25B - 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.

*************

***ELECTIVES – IV (semester-III)***

## 17272E32A - 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.

***ELECTIVES – IV (semester-III)***

# 17272E32B- 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.

**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 |

***ELECTIVES – V (semester-III)***

## 17272E33A - 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.

***ELECTIVES – V (semester-III)***

**17272E33B – POWER SYSTEM RESTRUCTURING AND DEREGULATION**

**3 1 0 4**

**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.

**5. 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**

**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


**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 |

***LECTIVES – VI (semester-III)***

## 17272E34A - 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. 
6. Dorf and Bishop,"Modern control Engineering', Addison Wesley, 1998.

***ELECTIVES – VI (semester-III)***

## 17272E34B - 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.

# Research Integrated Curriculum

The relationship between teacher and learner is completely different in higher education from what it is in school. At the higher level, the teacher is not there for the sake of the student, both have their justification in the service of scholarship. For the students who are the professionals of the future, developing the ability to investigate problems, make judgments on the basis of sound evidences, take decisions on a rational basis and understand what they are doing and why is vital. Research and inquiry is not just for those who choose to pursue an academic career. It is central to professional life in the twenty-first century.

It is observed that the modern world is characterized by heightened levels of complexity and uncertainty. Fluidity, fuzziness, instability, fragility, unpredictability, indeterminacy, turbulence, changeability, contestability: these are some of the terms that mark out the world of the twenty-first century. Teaching and research is correlated when they are co-related. Growing out of the research on teaching- research relations, the following framework has been developed and widely adopted to help individual staff, course teams and whole institutions analyse their curricula and consider ways of strengthening students understanding of and through research. Curricula can be:

**Research – Led: Learning about current research in the discipline**

Here the curriculum focus is to ensure that what students learn clearly reflects current and ongoing research in their discipline. This may include research done by staff teaching them.

**Research – Oriented: Developing research skills and techniques**

Here the focus is on developing student's knowledge of and ability to carry out the research methodologies and methods appropriate to their discipline(s)

**Research – Based: Undertaking research and inquiry**

Here the curriculum focus is on ensuring that as much as possible the student learns in research and or inquiry mode (i.e. the students become producers of knowledge not just consumers). The strongest curricula form of this is in those special undergraduate programmes for selected students, but such research and inquiry may also be mainstreamed for all or many students.

**Research- Tutored: engaging in research discussions**

Here the focus is on students and staff critically discussing ongoing research in the discipline.

All four ways of engaging students with research and inquiry are valid and valuable and curricula can and should contain elements of them.

Moreover, the student participation in research may be classified as,

Level 1: Prescribed Research
Level 2: Bounded Research
Level 3: Scaffolded Research
Level 4: Self actuated Research
Level 5: Open Research

Taking into consideration the above mentioned facts in respect of integrating research into the M.Tech Power system curriculum, the following Research Skill Based Courses are introduced in the curriculum.

| Semester | RSB Courses | Credits |
|---|---|---|
| I | Research Led Seminar | 1 |
| II | Research Methodology | 3 |
| II | Participation in Bounded Research | 2 |
| III | Design Project/ Socio Technical Project<br>( Scaffolded Research) | 4 |
| IV | Project Work | 12 |

**Blueprint for assessment of student's performance in Research Led Seminar Course**

- **Internal Assessment: 40 Marks**
    - Seminar Report (UG)/Concept Note(PG) : 5 X 4= 20 Marks
    - Seminar Review Presentation : 10 Marks
    - Literature Survey : 10 Marks

- **Semester Examination : 60 Marks**

  (Essay type Questions set by the concerned resource persons)

**Blueprint for assessment of student's performance in Design/Socio Technical Project**

- **Continuous Internal Assessment through Reviews: 40 Marks**
  - Review I : 10 Marks
  - Review II : 10 Marks
  - Review III : 20 Marks
- **Evaluation of Socio Technical Practicum Final Report: 40 Marks**
- **Viva- Voce Examination: 20 Marks**
- **Total: 100 Marks**

**Blueprint for assessment of student's performance in Research Methodology Courses**

**Continuous Internal Assessment: 20 Marks**

- Research Tools( Lab) : 10 Marks
- Tutorial: 10 Marks

**Model Paper Writing: 40 Marks**

- Abstract: 5 Marks
- Introduction: 10 Marks
- Discussion: 10 Marks
- Review of Literature: 5 Marks
- Presentation: 10 Marks

**Semester Examination: 40 Marks**

**Total: 100 Marks**

***********