# VINAYAKA MISSIONS UNIVERSITY

**SALEM, Tamilnadu, India.**

# M.E - POWER SYSTEMS ENGINEERING - FULL TIME CURRICULUM AND SYLLABUS - REGULATION - 2012

**FACULTY OF ENGINEERING AND TECHNOLOGY**

**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**

V.M.K.V. ENGINEERING COLLEGE,

Periya seeragapadi, Salem – 636 308.

Tamilnadu, India

# VINAYAKA MISSIONS UNIVERSITY, SALEM

## FACULTY OF ENGINEERING AND TECHNOLOGY

## M.E. POWER SYSTEMS ENGINEERING(REGULAR)

## REGULATION 2012

### YEAR-I

### SEMESTER – I

| Sl.No. | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| 1. | Applied Mathematics for Electrical Engineers | 3 | 1 | 0 | 4 |
| 2. | Power System Protection | 3 | 0 | 0 | 3 |
| 3. | Power Electronics in Power Systems | 3 | 0 | 0 | 3 |
| 4. | Power System Analysis | 3 | 1 | 0 | 4 |
| 5. | Elective – I | 3 | 0 | 0 | 3 |
| 6. | Elective – II | 3 | 0 | 0 | 3 |
| 7. | Power System Simulation – I Lab | 0 | 0 | 3 | 2 |
| | **TOTAL** | **18** | **2** | **3** | **22** |

### SEMESTER – II

| Sl.No. | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| 1. | Power System Operation | 3 | 1 | 0 | 4 |
| 2. | Power System Control | 3 | 0 | 0 | 3 |
| 3. | Transients in Power System | 3 | 0 | 0 | 3 |
| 4. | High Voltage Switchgear | 3 | 1 | 0 | 4 |
| 5. | Elective – III | 3 | 0 | 0 | 3 |
| 6. | Elective – IV | 3 | 0 | 0 | 3 |
| 7. | Power System Simulation – II Lab | 0 | 0 | 3 | 2 |
| | **TOTAL** | **18** | **2** | **3** | **22** |

**YEAR-II**

## SEMESTER – III

| Sl.No. | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| 1. | Elective – V | 3 | 1 | 0 | 4 |
| 2. | Elective – VI | 3 | 0 | 0 | 3 |
| 3. | Elective – VII | 3 | 0 | 0 | 3 |
| 4. | Project Work – Phase – I | 0 | 0 | 12 | 6 |
| | **TOTAL** | **9** | **1** | **12** | **16** |

## SEMESTER – IV

| Sl.No. | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| 1. | Project work – Phase II | 0 | 0 | 24 | 12 |
| | **TOTAL** | 0 | 0 | 24 | 12 |

## LIST OF ELECTIVES

| Sl.No. | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| 1. | Power System Dynamics | 3 | 0 | 0 | 3 |
| 2. | Soft Computing Techniques | 3 | 0 | 0 | 3 |
| 3. | Modelling and Analysis of Electrical Machines | 3 | 0 | 0 | 3 |
| 4. | EHV Power Transmission | 3 | 0 | 0 | 3 |
| 5. | Optimal Control Filtering | 3 | 0 | 0 | 3 |
| 6. | Power Quality | 3 | 0 | 0 | 3 |
| 7. | Power System Restructuring and Deregulation | 3 | 0 | 0 | 3 |
| 8. | Advanced Digital Signal Processing | 3 | 0 | 0 | 3 |
| 9. | Control System Design | 3 | 0 | 0 | 3 |
| 10. | Special Electrical Machines | 3 | 0 | 0 | 3 |
| 11. | Advanced Power System Dynamics | 3 | 0 | 0 | 3 |
| 12. | System Identification and Adaptive Control | 3 | 0 | 0 | 3 |
| 13. | Industrial Power System Analysis and Design | 3 | 0 | 0 | 3 |
| 14. | High Voltage Direct Current Transmission | 3 | 0 | 0 | 3 |
| 15. | Wind Energy Conversion Systems | 3 | 0 | 0 | 3 |
| 16. | AI Techniques to Power System | 3 | 0 | 0 | 3 |
| 17. | Power Electronics for Renewable Energy | 3 | 0 | 0 | 3 |
| 18. | Applications of MEMS Technology | 3 | 0 | 0 | 3 |
| 19. | Flexible AC Transmission System | 3 | 0 | 0 | 3 |
| 20. | Digital Signal Processing | 3 | 0 | 0 | 3 |
| 21. | Artificial Intelligence Applications to Power Systems | 3 | 0 | 0 | 3 |
| 22. | Intelligent Control | 3 | 0 | 0 | 3 |
| 23. | Computer Networks Engineering | 3 | 0 | 0 | 3 |

# APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS

**UNIT I - ADVANCED MATRIX THEORY 9**

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

**UNIT II - CALCULUS OF VARIATIONS 9**

Variation and its properties – Euler's equation – Functionals dependent on first and higher order derivatives – Functionals dependent on functions of several independent variables – Some applications – Direct methods: Ritz and Kantorovich methods.

**UNIT III - LINEAR PROGRAMMING 9**

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

**UNIT IV - DYNAMIC PROGRAMMING 9**

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

**UNIT V - RANDOM PROCESSES 9**

Classification – Stationary random processes – Auto Correlation – Cross Correlations – Power spectral density – Linear system with random input – Gaussian Process.

**Total Hours=45**

**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. Elsgoltis, " Differential Equations and Calculus of Variations ", MIR Publishers, Moscow (1970)
4. Gupta.A.S.,Calculus of Variations with Applications ,Prentice Hall of India, New Delhi, 1999.
5. Taha, H.A., "Operations research - An Introduction ", Mac Millan publishing Co., (1982).
6. Gupta, P.K.and Hira, D.S., "Operations Research ", S.Chand & Co., New Delhi, (1999).
7. Ochi, M.K. "Applied Probability and Stochastic Processes ", John Wiley & Sons (1992).
8. Peebles Jr., P.Z., "Probability Random Variables and Random Signal Principles ", McGraw Hill Inc., (1993).

# POWER SYSTEM PROTECTION

**UNIT I - INTRODUCTION 9**

General philosophy of protection – Characteristic function of protective relays – basic relay elements and relay terminology – basic construction of static relays – non-critical switching circuits.

**UNIT II - PROTECTION OF POWER APPARATUS 9**

Protection of generators stator phase fault protection –loss of excitation protection, generator off- line protection – Transformer protection – factors affecting differential protection – magnetizing inrush current – Application and connection of transformer differential relays – transformers over current protection – Example motor protection.

**UNIT III - PROTECTION OF TRANSMISSION SYSTEMS 9**

Bus protection – typical bus arrangements – transformer – bus combination – bus differential systems-line protection – classification of lines and feeders – Techniques applicable for line protection – distance protection for phase faults – Fault resistance and relaying – long line protection – Backup remote local and Breaker failure.

**UNIT IV - PROTECTION OF REACTORS, BOOSTERS & CAPACITORS 9**

Placement of reactors in power system – Types of reactor – reactor rating application and protection – booster in the power system – transformer tap changing – protection of boosters – capacitors in an interconnected power system – series – shunt – series shunt connections – protection of capacitors.

**UNIT V - DIGITAL PROTECTION 9**

Digital signal processing – Digital filtering in protection relays – digital data transmission – Numeric relay hardware – relay algorithms – distance relays – direction comparison relays – differential relays – software considerations – numeric relay testing – concepts of modern coordinated control system.

**L=45 Total = 45**

## REFERENCES


1. Stanley H.Horowitz (Ed), "Protecting relaying for power systems", IEEE Press, 1980.
2. Y.G. Paithankar and S.R Bhide, "Fundamentals of Power System Protection", Prentice -Hall of India, 2003
3. Y.G. Paithankar, "Principles of Power System Protection", Marcel Dekker Inc., 1998.
4. P.Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
5. Badri Ram and D.N. Vishwakarma, "Power System Protection and Switchgear", Tata McGraw- Hill Publishing Company, 2002.
6. J.L.Blackburn, "Power System Protection: Principles and Applications", Marcel Dekker, New York, 1998

# POWER ELECTRONICS IN POWER SYSTEMS

**UNIT I - INTRODUCTION 9**

Basic Concept of Power Electronics, Different types of Power Electronic Devices – Diodes, Transistors and SCR, MOSFET, IGBT and GTO's.

**UNIT II - AC TO DC CONVERTERS 9**

Single Phase and three phase bridge rectifiers, half controlled and Fully Controlled Converters with R, RL, AND RLE loads. Free Wheeling Diodes, Dual Converter, Sequence Control of Converters – inverter operation , Input Harmonics and Out put Ripple ,Smoothing Inductance – Power Factor Improvement effect of source impedance, Overlap, Inverter limit.

**UNIT III - DC TO AC CONVERTERS 9**

General Topology of single Phase and three phase voltage source and current source inverters- Need for feedback diodes in anti parallel with switches – Multi Quadrant Chopper viewed as a single phase inverter- Configuration of Single phase voltage source inverter: Half and Full bridge, Selection of Switching Frequency and Switching Device. Voltage Control and PWM strategies.

**UNIT IV - STATIC REACTIVE POWER COMPENSATION 9**

Shunt Reactive Power Compensation – Fixed Capacitor Banks, Switched Capacitors, Static Reactor Compensator, Thyristor Controlled Shunt Reactors (TCR) – Thyristor Controlled Transformer - FACTS Technology-Applications of static thyristor Controlled Shunt Compensators for load compensation ,Static Var Systems for Voltage Control, Power Factor Control and Harmonic Control of Converter Fed Systems.-

**UNIT V - POWER QUALITY 9**

Power Quality – Terms and Definitions – Transients – Impulsive and Oscillatory Transients – Harmonic Distortion – Harmonic Indices – Total Harmonic Distortion – Total Demand Distortion- Locating Harmonic Sources Harmonic s from commercial and industrial Loads –Devices for Controlling Harmonics Passive and Active Filters - Harmonic Filter Design-

**L=45 Total = 45**

**REFERENCES**


1. N.Mohan,T.M.Undeland and W.P.Robbins, Power Electronics : Converter, Applications and Design , John Wiley and Sons , 1989.
2. M.H.Rashid, Power Electronics, Prentice Hall of India, 1994.
3. B.K.Bose ,Power Electronics and A.C. Drives , Prentice Hall ,1986.
4. Roger C.Dugan , Mark .F. Mc Granaghan, Surya Santaso, H.Wayne Beaty, "Electrical Power Systems Quality", Second Edition, Mc Graw Hill, 2002.
5. T.J.E. Miller, Static Reactive Power Compensation, John Wiley and Sons, Newyork, 1982.
6. Mohan Mathur.R., Rajiv.K.Varma, "Thyristor Based FACTS controllers for Electrical Transmission Systems", IEEE press .1999.

# POWER SYSTEM ANALYSIS

**UNIT I - 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.

**UNIT II - POWER FLOW ANALYSIS** **9**

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

**UNIT III - SHORT CIRCUIT ANALYSIS** **9**

Review of fault calculations using sequence networks for different types of faults. Bus impedance matrix ($Z_{BUS}$) construction using Building Algorithm for lines with mutual coupling; Simple numerical problems. Computer method for fault analysis using $Z_{BUS}$ and sequence components. Derivation of equations for bus voltages, fault current and line currents, both in 012 frame and abc frame using Thevenin's Equivalent and $Z_{BUS}$ matrix for different faults.

**UNIT IV - OPTIMAL POWER FLOW** **9**

Introduction: 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 V - VOLTAGE STABILITY ANALYSIS, STEADY-STATE** **9**

Transmission system aspects: SLIB system, maximum deliverable power, power-voltage relationship, generator reactive power requirement, network versus load P-V characteristics, Instability scenario, effect of compensation and series, shunt, SVC, V-Q curves, effect of adjustable transformer ratios.

**L= 45 T=15 TOTAL = 60**

**REFERENCES**

1. Stagg G W., El. Abiad A.H. "Computer Methods in Power System Analysis ", McGraw Hill, 1968.
2. Elgerd O.I., "Electrical Energy Systems Theory – An Introduction", Tata McGraw, 2002.
3. Kundur.P., "P.S. Stability and Control", McGraw Hill, 1994.
4. T.V. Cutsem and C.Vournas," Voltage Stability of Electric Power Systems", Kluwer Publishers, 1998.
5. A.J.Wood and B.F.Wollenberg,"Power Generation Operation and Control", John Wiley and sons, New York, 1996.

# POWER SYSTEM SIMULATION – I LAB

1. Computation of parameters and modeling of transmission lines.
2. Formation of bus admittance and bus impedance matrices and solution of networks.
3. Solution of power flow using Gauss - Seidel method.
4. Solution of power flow using Newton - Raphson method.
5. Solution of power flow using fast decoupled method.
6. Symmetrical fault analysis.
7. Unsymmetrical fault analysis.

# POWER SYSTEM OPERATION

**1. LOAD FORECASTING 9**

Introduction – Estimation of Average and trend terms – Estimation of periodic components – Estimation of Stochastic components : Time series approach – Auto- Regressive Model, Auto-Regressive Moving – Average Models – Kalman Filtering Approach – On- line techniques for non stationary load prediction.

**2. UNIT COMMITMENT 9**

Constraints in unit commitment – Spinning reserve, thermal unit constraints, other constraints – Solution using Priority List method, Dynamic programming method - Forward DP approach , Lagrangian relaxation method – adjusting $\lambda$.

**3. GENERATION SCHEDULING – THERMAL SYSTEM 9**

The Economic dispatch problem – Thermal system dispatching with networklosses considered – The Lambda –iteration method – Gradient method ofeconomic dispatch – economic dispatch with Piecewise Linear cost functions-economic dispatch using dynamic programming – transmission system effects -A two generator system , coordination equations, incremental losses and penalty factors.

**4. GENERATION SCHEDULING – HYDRO THERMAL SYSTEMS 9**

Long Range Hydro – Scheduling – Short Range Hydro Scheduling - Hydro Electric plant models – Scheduling problems – The Short term Hydothermal Scheduling problem – Short term hydro-scheduling : A Gradient Approach- Hydro units in series (hydraulically coupled) – Pumped –Storage Hydro- Scheduling with a $\lambda$-$\gamma$ iteration – Dynamic programming solution to the Hydro Thermal scheduling problem.

**5. INTERCHANGE OF POWER AND ENERGY 9**

Economy interchange between interconnected utilities – interchange evaluation with unit commitment – Multiple – utility interchange transactions – Power Pools: The Energy Broker system, Allocating pool savings – Transmission Effects and Issues : Transfer limitations, wheeling, rates for transmission services in multiparty utility transactions – Transactions involving Nonutility Parties.

**L= 45 TOTAL = 60**

**REFERENCES**


1. Allen J.Wood and Bruce F Wollenberg, "Power Generation, Operation and Control",John Wiley and sons, Newyork, 1996.
2. A.K.Mahalanabis, D.P.Kothari, S.I.Ahson, "Computer Aided Power System Analysis and Control", Tata Mcgraw Hill Publishing Co. Ltd., NewDelhi 1988.

# POWER SYSTEM CONTROL

## 1. AUTOMATIC GENERATION CONTROL 9

Fundamentals of speed governing - control of generating unit Power output – composite regulating characteristic of Power Systems – Response rates of turbine – governing systems – fundamentals of automatic generation control – Implementation of AGC - development of state variable model for a two area Power System for use in simulation of AGC. Underfrequency Load Shedding and computation of settings for underfrequency relays.

## 2. REACTIVE POWER AND VOLTAGE CONTROL 9

Modelling of AVR loops : Components – stability compensation - Production and absorption of reactive Power – methods of voltage control - shunt reactors – shunt capacitors – series capacitors – synchronous condensers – static var systems – Principle of transmission system compensation – modeling of reactive compensating devices – Application of tap changing transformers to transmission systems – distribution system voltage regulation – modeling of transformer ULTC control systems .

## 3. SECURITY CONTOL OF POWER SYSTEMS 9

System operating states by security control functions – monitoring, evaluation of system state by contingency analysis – corrective controls (Preventive, emergency and restorative ) - Energy control center – SCADA system – functions – monitoring , data acquisition and controls – EMS system.

## 4. STATE ESTIMATION 9

Maximum likelihood Weighted Least - Squares Estimation :- Concepts - matrix formulation - Example for Weighted Least - Squares state estimation ; State estimation of an AC network: development of method , Typical results of state estimation on an AC network, State Estimation by Orthogonal Decomposition algorithm – Introduction to Advanced topics : Detection and Identification of Bad Measurements , Estimation of Quantities Not Being Measured , Network Observability and Pseudo- measurements - Application of Power Systems State Estimation .

## 5. POWER SYTEM CONTROL UNDER DEREGULATED ENVIRONMENT 9

New system structures under competition – Classification of operational tasks in today's power industry – Temporal decomposition within the real time operation – classification of operational tasks in the competitive industry – meeting predicted demand in today's industry – meeting demand in the new industry – balancing supply and demand in real time - Load frequency control under deregulated environment.

***L= 45 T= 15 Total = 60***

## REFERENCES


1. Elgerd O.I, "Electric Energy System Theory - an Introduction" - Tata McGraw Hill, New Delhi – 2002.
2. Kundur .P; "Power System Stability and Control" EPRI Publications, California, 1994.
3. Allen J.Wood and Bruce .F. Woolenberg, "Power Generation Operation and Control", John Wiley & sons New York, 1996.
4. Mahalanabis A.K., Kothari. D.P. and Ahson.S.I., "Computer Aided Power System Analysis and Control", Tata McGraw Hill publishing Ltd , 1984.
5. Marija Ilic, F.Galiana, L.Fink, "Power System Restructuring : Engineering and Economics" Kluwer Academic Publishers, 2000.
6. Vaibhav Donde, M.A. Pai & Ian A.Hiskens - "Simulation & Optimization in an AGC system after deregulation" IEEE transactions on Power Systems Vol:16, No.3, Aug 2001.

# TRANSIENTS IN POWER SYSTEMS

**1.INTRODUCTION AND LIGHTNING SURGES 9**

Review of various types of power system transients – effect of transients on power systems- relevance of the study and computation of power system transients. Electrification of thunderclouds – lightning current stages – lightning current parameters and their values – stroke to tower and midspan – induced lightning surges.

**2. SWITCHING SURGES 9**

Closing and reclosing of lines – load rejection – fault initiation – fault clearing – short line faults – FerroResonance – isolator switching surges – temporary over voltages – surges on an integrated systems – switching – harmonics.

**3. COMPUTATION OF TRANSIENTS IN CONVERSION EQUIPMENT 9**

Traveling wave method – Beweley's Lattice diagram – analysis in time and frequency domain – eigenvalue approach – Z-transform.

**4. INSULATION CO ORDINATION 9**

Over voltage protective devices – shielding wires, rods gaps, surge diverters, principles of insulation co-ordination – recent advancements in insulation co ordination – Design of EHV system – Insulation co ordianation as applied to transformer, substations.

**5. CASE STUDIES-SIMULATION OF ELECTROMAGNETIC TRANSIENTS 9**

(i) Energisation of a single phase 0.95 pf load from a non ideal source and a realistic line representation.
(ii) Energisation of a single phase 15 mile long line from an ideal voltage source (equivalent-Π ) – lumped and distributed parameter representation.
(iii) Energisation of a 3 phase, 15 mile distributed parameter line connected to a transformer and RL load, (three phase closure simulations).
(iv) Same as above but only one phase closed.
(v) Energisation of a 120 mile transposed line from an ideal voltage source.(Adequate model needed)

***L= 45 Total = 45***

## REFERENCES


1. Allan Greenwood, "Electrical Transients in Power Systems", Willey Interscience, New York, 1971.
2. Klaus Ragaller, "Surges in High Voltage Networks", Plenum Press, New York,1980.
3. Diesendorf, W., "Over Voltage on High Voltage Systems", Renselaer Bookstore, Troy New York, 1971.
4. Peterson,H.A., "Transient in Power Systems", Dover Publication, New York, 1963.
5. Rakosh das Begamudre, "Extra High Voltage AC Transmission Engineering", Wiley Eastern Ltd, New Delhi, 1990.
6. C.S.Indulkar, DP Kothari, "Power System Transients" - A Statistical approach , Prentice Hall 1996.

# HIGH VOLTAGE SWITCH GEAR

**1. INTRODUCTION** **7**

Insulation of switchgear - rated and tested voltage coordination between inner and external insulation. Insulation clearances in air, oil $SF_6$ and vacuum, bushing insulation, solid insulating materials – dielectric and mechanical strength consideration.

**2. CIRCUIT INTERRUPTION** **10**

Switchgear terminology – Arc characteristics – direct and alternating current interruption – arc quenching phenomena – computer simulation of arc models – transient re-striking voltage – RRRV-recovery voltage-current chopping-capacitive current breaking-auto re-closing.

**3. SHORT CIRCUIT CALCULATIONS AND RATING OF CIRCUI BREAKERS** **10**

Types of faults in power systems-short circuit current and short circuit MVA calculations for different types of faults-rating of circuit breakers – symmetrical and asymmetrical ratings.

**4. CIRCUIT BREAKERS** **10**

Classification of circuit breakers-design, construction and operating principles of bulk oil, minimum oil, airblast, $SF_6$ and vacuum circuit breakers – Comparison of different types of circuit breakers.

**5. TESTING OF CIRCUIT BREAKERS** **8**

Type tests and routine tests – short circuit testing-synthetic testing of circuit breakers-recent advancements in high voltage circuit breakers-diagnosis.

***L = 45   TOTAL = 45***

## REFERENCES


1. Chunikhin, A. and Zhavoronkov, M., “High Voltage Switchgear Analysis and Design”, Mir Publishers, Moscow, 1989.
2. Kuffel, E., Zaengl, W.S., and Kuffel J., High Voltage Engineering Fundamentals, Newness, Second Edition, Butterworth-Heinemann Publishers, New Delhi, 2000
3. Flursscheim, C.H. (Editor), Power circuit breaker-theory and design, IEE Monograph Series 17, Peter Peregrinus Ltd., Southgate House, Stevenage, Herts, SC1 1HQ, England, 1977.
4. Ananthakrishnan S and Guruprasad K.P., Transient Recovery Voltage and Circuit Breakers, Tata McGraw-Hill Publishing Compa ny Ltd., New Delhi, 1999.
5. IEEE Standard Collection, Surge Protectino C62, 1995 Editions, (Institute of Electrical and Electronics Engineers, Inc.), USA.
6. Funio Nakanishi, Switching Phenomena in high voltage circuit breakers, Marcel Dekker Inc., New York, 1991.

## POWER SYSTEM SIMULATION – II LAB

### LIST OF EXPERIMENTS

1. Contingency analysis: Generator shift factors and line outage distribution factors
2. Small signal stability analysis: SMIB and Multi machine configuration
3. Transient stability analysis of Multi – machine configuration
4. Economic dispatch with line flow constraints
5. Unit commitment: Priority-list schemes and dynamic programming
6. Co-ordination of over current and distance relays for radial line protection
7. Induction motor starting analysis
8. Analysis of switching surge using EMTP.

# ELECTIVE

## HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

### 1. DC POWER TRANSMISSION TECHNOLOGY 9

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

### 2. ANALYSIS OF HVDC CONVERTERS 9

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

### 3. CONVERTER AND HVDC SYSTEM CONTROL 9

General principles of DC link control-converter control characteristics-system 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 TOTAL = 45**

**REFERENCES**

**1.** Padiyar, K.R., "HVDC Power Transmission System", Wiley Eastern Limited, New Delhi 1990. First edition.

2. Edward Wilson Kimbark, "Direct Current Transmission", Vol. I, Wiley interscience, New York, London, Sydney, 1971

3. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering" New Age International (P) Ltd., New Delhi, 1990.

4. Arrillaga, J., "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983.

# ELECTIVE
# EHV POWER TRANSMISSION

**1. INTRODUCTION** **6**
Standard Transmission Voltages – 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** **8**
Calculation of Resistance, Inductance and Capacitance – Calculation of sequence inductances and capacitances – Line parameters for Modes of propagation.

**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 12

Power losses and audible losses : $I^2R$ Loss and Corona Loss -Attenuation of Traveling Waves Due to 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 - The CIGRE Formula - The RI Excitation Function -Measurement of RI, RIV and Excitation Function - Design of Filter.

**5. ELECTROSTATIC FIELD OF EHV LINES** **10**
Capacitance of Long Object - Calculation of Electrostatic Field of AC Lines Effect of High Field on Humans, Animals, and Plants - Meters and Measurement of Electrostatic Fields - Electrostatic Induction in Unenergised Circuit of a D/C Line - Induced Voltages in Insulated Ground Wires - Electromagnetic Interference.

***L = 45 TOTAL = 45***

## REFERENCE

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

# ELECTIVE
# DIGITAL SIGNAL PROCESSING

**1. DISCRETE TIME SIGNALS AND SYSTEMS** 9

Representation of discrete time signal – classifications – Discrete time – system – Basic operations on sequence – linear – Time invariant – causal – stable – solution to difference equation – convolution sum – correlation – Discrete time Fourier series – Discrete time Fourier transform.

**2. FOURIER AND STRUCTURE REALIZATION** 9

Discrete Fourier transform – properties – Fast Fourier transform – Z-transform – structure realization – Direct form – lattice structure for FIR filter – Lattice structure for IIR Filter **.**

**3.FILTERS** 9

FIR Filter – windowing technique – optimum equiripple linear phase FIR filter – IIR filter – Bilinear transformation technique – impulse invariance method – Butterworth filter – Tchebyshev filter.

**4.MULTISTAGE REPRESENTATION** 9

Sampling of band pass signal – antialiasing filter – Decimation by a n integer factor – interpolation by an integer factor – sampling rate conversion – implementation of digital filter banks – sub-band coding – Quadrature mirror filter – A/D conversion – Quantization – coding – D/A conversion – Introduction to wavelets.

**5.DIGITAL SIGNAL PROCESSORS** 9

Fundamentals of fixed point DSP architecture – Fixed point number representation and computation – Fundamentals of floating point DSP architecture – floating point number representation and computation – study of TMS 320 C 50 processor – Basic programming – addition – subtraction – multiplication – convolution – correlation – study of TMS 320 C 54 processor – Basic programming – addition – subtraction – multiplication – convolution – correlation**.**

L = 45 Total = 45

**REFERENCES**

1. John G.Proakis, Dimitris G.Manolakis, "Digital Signal Processing: Principles, Algorithms and Applications", PHI.
2. S.Salivahanan, A.Vallavaraj and C.Gnanapriya "Digital Signal Processing", TMH, 2000.
3. A.V. Oppenheim and R.W.Schafer, Englewood "Digital Signal Processing", Prentice-Hall, Inc, 1975.
4. Rabiner and Gold, "Theory and Application of Digital Signal Processing", A comprehensive, Industrial – Strength DSP reference book.
5. B.Venkatramani & M.Bhaskar, "Digital Signal Processors Architecture, Programming and Applications", TMH, 2002.

# ELECTIVE
# FLEXIBLE AC TRANSMISSION SYSTEMS

**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, and 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), Fixed Capacitor (FC).

*L = 45 TOTAL = 45*

**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 High 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.

# ELECTIVE

## POWER QUALITY

**1. INTRODUCTION 9**

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

**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.

**TOTAL : 45 PERIODS**

**TEXT BOOKS**


1. Arindam Ghosh "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, 2002
2. G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, 1994(2nd edition)
3. Power Quality - R.C. Duggan
4. Power system harmonics –A.J. Arrillga
5. Power electronic converter harmonics –Derek A. Paice

## ELECTIVE

### SPECIAL ELECTRICAL MACHINES

**1. SYNCHRONOUS RELUCTANCE MOTORS** **9**

Constructional features: axial and radial air gap Motors. Operating principle, reluctance torque – phasor diagram, motor characteristics – Linear induction machines.

**2. STEPPING MOTORS** **9**

Constructional features, principle of operation, modes of excitation torque production in Variable Reluctance (VR) stepping motor, Dynamic characteristics, Drive systems and circuit for open loop control, Closed loop control of stepping motor.

**3. SWITCHED RELUTANCE MOTORS** **9**

Constructional features-principle of operation-Torque equation-Power Controllers-Characteristics and control Microprocessor based controller.

**4. PERMANENT MAGNET SYNCHRONOUS MOTORS** **9**

Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power controllers, Torque speed characteristics, Self control, Vector control, Current control schemes.

**5. PERMANENT MAGNET BRUSHLESS DC MOTORS** **9**

Commutation in DC motors, Difference between mechanical and electronic commutators, Hall sensors, Optical sensors, Multiphase Brushless motor, Square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics, Controllers-Microprocessor based controller.

***TOTAL : 45 PERIODS***

***TEXT BOOKS***

1. Miller, T.J.E. "Brushless permanent magnet and reluctance motor drives ", Clarendon Press, Oxford, 1989.
2. Kenjo, T, "Stepping motors and their microprocessor control ", Clarendon Press, Oxford, 1989.
3. LIM

**REFERENCES**

1. Kenjo, T and Naganori, S "Permanent Magnet and brushless DC motors ", Clarendon Press, Oxford, 1989.
2. Kenjo, T. Power Electronics for the microprocessor Age, 1989.
3. B.K. Bose, "Modern Power Electronics & AC drives"
4. R.Krishnan, "Electric Motor Drives – Modeling, Analysis and Control", Prentice-Hall of India Pvt. Ltd., New Delhi, 2003

## ELECTIVE
## POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

**1. INTRODUCTION 9**

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems.

**2. ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION 9**

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

**3. POWER CONVERTERS 9**

Solar: Block diagram of solar photo voltaic system -Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection Of inverter, battery sizing, array sizing

Wind: three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters.

**4. ANALYSIS OF WIND AND PV SYSTEMS 9**

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

**5. HYBRID RENEWABLE ENERGY SYSTEMS 9**

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

**TOTAL : 45 PERIODS**

**REFERENCES:**


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