Curriculum of M.Tech. (Electrical Engineering)

SPECIALIZATION: MACHINE & DRIVES

FIRST SEMESTER

A. THEORY						
Serial No	**Subject Code**	**Subject**	**L-T-P**			**Credits**
			L	**T**	**P**	
1	EEMD101	Fundamentals of Electrical Machine & Drives	4	0	0	4
2	EEMD102	Power Electronics & Machine Drives	3	1	0	4
3	EEMD103	Modern Control Theory	4	0	0	4
4	EEMD104	Advanced Engineering Mathematics	3	1	0	4
5	EEMD105	Elective-I	4	0	0	4
			Total			**20**

A. LABORATORY/PRACTICAL						
Serial No	**Subject Code**	**Subject**	**L-T-P**			**Credits**
			L	**T**	**P**	
1	EEMD191	Machine & Drives Lab	0	0	3	2
2	EEMD192	Control and Power Electronics Lab	0	0	3	2
3	EEMD181	Seminar-I	0	2	0	1
					Total	**5**

Elective-I :

EEMD105A	Advance Theory & Analysis of AC Machine
EEMD105B	Traction Drives
EEMD105C	Special Electrical Machine

SECOND SEMESTER

A. THEORY						
Serial No	**Subject Code**	**Subject**	**L-T-P**			**Credits**
			L	**T**	**P**	
1	EEMD201	Mathematical Modeling & Analysis of Electrical Machine	3	1	0	4
2	EEMD202	Electric Drives & Their Control	3	1	0	4
3	EEMD203	Advanced Electrical Drives	3	1	0	4
4	EEMD204	Elective-II	4	0	0	4
5	EEMD205	Elective-III	4	0	0	4
			Total			**20**

A. LABORATORY/PRACTICAL						
Serial No	**Subject Code**	**Subject**	**L-T-P**			**Credits**
			L	**T**	**P**	
1	EEMD281	Seminar-II	0	2	0	1
2	EEMD291	Drives & Simulation Lab	0	0	3	2
					Total	**3**

Elective-II :

EEMD204A	Engineering Optimization
EEMD204B	Microcomputer Controlled Drives
EEMD204C	Computer Aided Design Of Electrical Machines

Elective-III :

EEMD205A	Finite Element Method Of Electrical Machine
EEMD205B	Smart Grid Technologies
EEMD205C	EHV AC & DC Transmission

THIRD SEMESTER

Serial No	Subject Code	Subject	L-T-P	Credits
1	EEMD381	Pre submission Defense of Dissertation	0-0-0	4
2	EEMD382	Dissertation (Part-I)	0-0-0	18
			Total	**22**

FOURTH SEMESTER

Serial No	Subject Code	Subject	L-T-P	Credits
1	EEMD481	Post submission Defense of Dissertation	0-0-0	6
2	EEMD482	Dissertation (Part-II)	0-0-0	18
3	EEMD483	Comprehensive Viva Voce	0	4
			Total	**28**

FUNDAMENTALS OF ELECTRICAL MACHINE & DRIVES
EEMD101

Course Outcomes:

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

I. Comprehend basic concepts, principles in dc machines, ac machines and drives.

II. Formulate and solve power flow problems, analyze performance of dc and acmachines.

III. Select suitable motor and drive according to the application.

IV. Test and analyze the parameters and performance of the motors.

Course Contents:

Electromechanical energy conversion, field energy, co energy, mechanical forces in electromagnetic system; dc machines, construction, windings, types, dc motor and generators, commutation process, Interpoles; Induction (Asynchronous) motors, construction, rotating magnetic field, squirrel cage and slip ring motors, equivalent circuit, power flow, starting, speed control, single phase induction motors; Synchronous motor and generator construction, equivalent circuit, power and torque equations, power factor control, BLDC and SRM; Basics of electrical drives and control, dynamics of electrical drives, dc motor drives, induction motor drives.

Reference Books:

1. P. C. Sen, “Principles of electric machines and power electronics”, John Wiley and Sons, Second edition, 1997.

2. G. K. Dubey, “Fundamentals of electrical drives”, Second edition, (sixth reprint), Narosa Publishing house, 2001.

3. D. P. Kothari, I. J. Nagrath, ‘Electric Machines’, Tata McGraw Hill Publication, Fourth edition, reprint 2012.

4. B. K. Bose, “Modern power electronics and ac drives”, Pearson Education, Asia, 2003.

POWER ELECTRONICS AND MACHINE DRIVES
EEMD 102

Course Outcomes:
Acquire knowledge of power electronics and drives

Course Contents:
Power Electronic Devices: Diodes, Transistors, Thyristors, MOSFET and IGBT – operating principle and characteristics, Data sheet ratings, gate drive circuits;
Single and three phase half controlled and fully controlled AC/DC bridge converter with motor loads: operation in continuous/discontinuous conduction mode, effect of input line inductance;
Torque-speed characteristics of converter controlled separately excited dc motor in continuous and discontinuous mode of conduction; Series and parallel operation of converters, power factor improvement, 12 pulse operation, transformer connection, dual converters;
Basic DC-DC converters: buck, boost buck-boost and Cuk converter, operation, waveforms and design; DC-DC choppers: basic voltage commutated thyristor chopper analys , Separately excited
DC motor drive using DC-DC choppers , four quadrant operation, dynamic and regenerative braking of series DC motor using choppers;
DC-AC inverters using gate controlled devices: single phase and three phase square wave inverters, operation waveforms and harmonics; Output voltage control in single phase square wave inverter using phase shift, harmonic analysis; Operating principles of single phase and three phase PWM inverters, modulation techniques and comparison among different PWM techniques;
Variable frequency operation of three phase induction motors: Steady state analysis, Torque speed , current-speed and slip frequency -speed characteristics; Operating limits with constant volts/Hz and constant air gap flux operation, implementation using PWM VSI

Reference Books :
1. Rashid M.H., Power Electronics, 4 edition, Pearson Prentice Hall;, 19 July 2013
2. G.K.DubeyDoradla, Joshi, Sinha, Thyristorised Power Controllers, illustrated, New Age International, 1986
3. C.W.Lander, Power Electronics, 3 Sub edition, McGraw-Hill Europe;, April 1, 1994
4. B. R. PELLY, Thyristorised power controlled converters &cycloconverters, , Wiley-Blackwell, 1 January 1971
5. Joseph Vithayathi, Power Electronics appliCation, , McGraw Hill Education, 9 April 2010
6. Philip Kranes, Power Electronics, 1 edition, OUP, 1997**,** Ned Mohan,Tore M. Undeland,
7. William P. Robbins, Power Electronics, 3rd Revised edition, Wiley, 8 November 2002

MODERN CONTROL THEORY
EEMD 103

Course Outcomes:
Application of advanced control principles in linear and non-linear systems

Course Contents:
Introduction: Systems, modeling, analysis and control, continuous-time and discrete-time.
State Variable Descriptions: Introduction, concept of state, state equations for dynamic systems, state diagrams.
Physical Systems & State Assignments: Linear continuous-time and discrete-time models, non-linear models, local linearization of non-linear model.

Solution of State Equations: Existence and uniqueness of solution, linear time-invariant continuous-time state equations, linear discrete-time state equations.
Controllability &Observability: Concept of controllability &observability, controllability and observability tests for continuous -time systems, controllability and observability of discrete-time systems, canonical forms of state models.
State models and input-output descriptions: Input-output maps from state model and vice-versa, transfer matrix, output controllability, reducibility.
Modal Control: Introduction, Effect of state feedback on controllability and observability, pole placement by state feedback; Full order observers, Reduced-order observers; deadbeat control by state feedback, deadbeat observers.
Fractional Order Controller: Fractional order calculus, Fractional order transfer function modeling, Frequency domain analysis of fractional order controller, Time domain analysis of time domain controller.

Reference Books :
1. Digital Control & State Variable Mathods – M. Gopal, Tata Macgrow
2. Modern Control System Theory by M. Gopal
3. Linear Systems by Thomas Kailath.
4. Modern Control Engg. by K. Ogata.

ADVANCED ENGINEERING MATHEMATICS
EEMD104

Course Outcomes:
I.. Develop a conceptual basis for Linear algebra.+
II. Equip the Students with a thorough understanding of vector spaces and optimization techniques
Course Contents:
Complex Variables:
Review of complex variables, Conformal mapping & transformations, Function of complex variables, Pole and singularity, Integration with respect to complex argument, Residues and basic theorems on residues.
Numerical Analysis:
Introduction, Interpolation formulae, Difference equation, Roots of equations,
Solution of simultaneous linear and non-linear equations, Solution techniques for ODE and PDE, Introduction to stabilty, Matrix, eigen value and eigen vector problems.
Optimization Technique:
Calculus of several variables, Implicit function theorem, Nature of singular points, Necessary and sufficient conditions for optimization, Elements of calculus variation, Constrained Optimization, Lagrange multipliers, Gradient method, Dynamic programming.
Linear Algebra:
Vector space, Linear dependence of vectors, basis, linear transformations, inner product space, rank and inverse of a matrix, solution of algebraic equations, consistency conditions, Eigen values and eigen vectors, Hermitian and Skew Hermitian matrices.

Reference Books:
1. John B. Conway, Functions of one complex variable, Springer International.
2. James Ward Brown &Ruel V. Churchill, Complex variable and application.,McGraw Hill International edition .
3. John H. Mathews, Numerical Methods for Mathematics , science and Engineering, PHI
4. D.C. Sanyal and K. Das, A text Book of Numeriacl analysis, U.N. Dhar& Sons Pvt. Ltd.
5. S.S.Rao,,Optimisation theory and application, Wiely Eastern limited
6. Hoffman &Kunze. R, Linear Algebra, PHI

ADVANCED THEORY AND ANALYSIS OF AC MACHINES
EE105A

Physical model, Different reference frame, Transformations, Primitive Machine, Dynamic variable, Formulation of dynamic equations of a generalized machine, Maxwell equations; Electric field of Transformers, Shaft voltages and fluxes, bearing currents, induction motor modelling, oscillations In Induction machines, Asymmetries in stator and rotor windings, Asynchronous-synchronous Operation of synchronous machine; Modelling, Operational Impedances, Time constants, Stability, Power angle characteristics, Symmetrical and Asymmetrical short circuit analysis, Measurement of Reactance, Power Systems.

TRACTION DRIVES
EEMD105B

Course Outcomes :
Application of Power System and Electrical Machines in traction systems

Course Contents:
Introduction to Electric Traction Systems, preliminary investigations of energy consumption, Traction Drives rating, Traction Motors, Conventional DC & AC traction drives, Semiconductor converter controlled drives, Polyphase AC motors for traction drives, Battery operated vehicles, Diesel-Electric Traction systems Conservation of Electrical energy. Battery operated vehicles.

Reference Books :
1. A.T.Dover, Electric Traction, 4th edition, Sir Isaac Pitman & Sons Ltd, 1963
2. G.K.Dubey, Dorodla, Joshi &Sinha, Thyristorised Power Controllers, Wiley, (November 12, 1986)
3. Pratab, Modern Electric Traction, PritamSurat& Brothers, 1973

SPECIAL ELECRICAL MACHINE
EEMD105C

Course Outcomes:
Exploring possibilities of special machines in industrial applications

Course Contents:
Review of drives. Principle, construction, operation & control of special machines: switch reluctance motor, brushless DC motor, stepper motor, linear induction motor, hysteresis motor. Energy efficient motors. Control and applications of special machines.

Reference Books:
1. J.M.D. Murphy, Power electronics control of AC machine, 1st edition, Franklin Book Co, March
1988
2. T.J.E. Miller, BrushlessPermanent-magnet and reluctance motor Drives, Clarendon Press, 2 March 1989
3. B.K.Bose, Power electronics and variable frequency drives edited, IEEE Press, 1997
4. J.C. Andreas, Energy efficient electric motors, 3 edition, CRC Press, August 30, 2004
5. K Venkataratnam, Special Electrical Machines, First edition, Universities Press, 2008

MATHEMATICAL MODELING AND ANALYSIS OF ELECTRICAL MACHINES
EEMD201

Course Outcomes:

At the end of this course students will be able to,

I.. Analyze electromechanical devices and machines

II. Use reference frame theory to study and analyze the behavior of induction andsynchronous machines

III. Calculate the machine inductances for use in machine analysis

IV. Model the electrical machine from the terminal junction with transmission systems

Course Contents:

Principle of unified machine theory, generalized torque equation, performanceevaluation of DC machine and speed control, three phase induction motortransformationmethods, stationary, rotor and synchronous frames andcorresponding equivalent circuits, three phase synchronous motor:representation, Park transformation, drives, various control techniques, conceptof space vector, field oriented control and direct torque control of IM, permanentmagnet synchronous motors- machine model (d-q) and control methods, reluctancemachines models.

Reference Books:

1. P. C. Krause, “Analysis of Electric Machinery”, McGraw Hill, New York, 1987.
2. CheeMunOng, “Dynamic simulation of Electrical Machinery using Matlab/Simulink” Prentice Hall PTR, 1997
3. P. Vas, “Vector Control of A.C. Machines”, Clarendon Press, Oxford 1990.
4. J .M. D. Murphy and F.G. Turnbull, “Power Electronic Control of AC motors”,

ELECTRIC DRIVES AND THEIR CONTROL
EEMD202

Characteristics of Electric Motors: Characteristics of DC motors, 3-phase Induction motors and Synchronous motors. Starting and Breaking of Electric motors. Status of DC and AC Drives.

Dynamics of Electric Drives: Parts of electric drives electric motors, power modulators, sources, control unit, and mechanical system. Fundamental torque equations.Multi-quadrant operation. Equivalent values of drive parameters-loads with rotational motion and translational motion, components of load torque, nature and classification of load torques. Dynamic conditions of a drive system.Energy loss in transient operations, load equalization.

Motor Power Rating: Power losses of motors, heating and cooling of electric motors.

Thermal model of motor for heating and cooling, classes of motor duty, Determination of motor rating, continuous duty, short time duty and intermittent periodic duty.Equivalent current, torque and power for fluctuating and intermittent loads.

Control of electric Drives: Modes of operation. Closed-loop control of drives.Current-limit control. Closed-loop torque, and speed control. Closed-loop control of multi motor drives.Speed and current sensing.Phase-locked-loop control.

DC Motor Drives: Starting, Braking, and speed control Transient Analysis of separately excited motor with armature and field control, energy losses during transient operation. Phase controlled converter DC drives, dual-converter control of DC drive, power factor, supply harmonics and ripple in motor current. Chopper control DC drives. Source Current harmonics.

3-Phase Induction Motor Drives: Starting, Breaking and Transient Analysis. Calculation of energy losses. Speed Control, Staler Voltage control. Variable Frequency control from voltage and current sources, Slip power recovery-Static Scherbius and Cramer Drives.
Synchronous Motor Drives: Starting, Pull in and Braking of Synchronous motor. Speed control-variable frequency control, Cycloconverter control.
Brushless DC Motor, Linear Induction Motor, Stepper Motor and Switched Reluctance Motor Drives: Important Features and applications.
Energy Conservation in Electrical Drives: Losses in electrical drive system. Measures for energy conservation in electric drives, Use of efficient motor, Energy efficient operation of drives, Improvement of power factor and quality of supply.

Reference Books:
1. Dynamic & Control Of Electrical Drives, Piotrwach, Springer
2.Digital Control Of Electrical Drive, Slobodan N.Vucosavic, Springer

ADVANCED ELECTRICAL DRIVES
EEMD203

Vector Control of Induction Motor: Principles of vector control, direct vector control, derivation of indirect vector control, implementation-block diagram; estimation of flux, flux weakening operation.
Control of Synchronous Motor Drives: Synchronous motor and its characteristics- Control strategies-Constant torque angle control- power factor control, constant flux control, flux weakening operation, Load commutated inverter fed synchronous motor drive, motoring and regeneration, phasor diagrams.
Control of Switched Reluctance Motor Drives: SRM Structure-Stator Excitation-techniques of sensor less operation-convertor topologies-SRM Waveforms-SRM drive design factors-Torque controlled SRM-Torque Ripple-Instantaneous Torque control -using current controllers-flux controllers.
Control of BLDC Motor Drives: Principle of operation of BLDC Machine, Sensing and logic switching scheme, BLDM as Variable Speed Synchronous motor-methods of reducing Torque
pulsations -Three-phase full wave Brushless dc motor -Sinusoidal type of Brushless dc motor current controlled Brushless dc motor Servo drive.

Reference Books:
1. Advanced Electric Drives, NED MOHAN, Wiley
2. Applied control of electrical Drive, DucoW.J.Pulle, Pete Durnel& Andre Veltman, Springer
3. Advance electric Drive Vehicles, Ali Emadi, CRC Press

ENGINEERING OPTIMIZATION
EEMD204A

Course Outcomes:
Upon successful completion of this course students will be able to,
I. Explain and use the basic theoretical principles of optimization and various optimization techniques.
II. Develop and select appropriate models corresponding to problem descriptions in engineering and solve them correctly.
III. Analyze and solve complex optimization problems in engineering
IV. Design optimization models and use them in solving real life problems
V. develop and Implement optimization algorithms and use software tools to solve problems in engineering

VI. Make sound recommendations based on these solutions, analysis and limitations of these models.

Course Contents:
Introduction to optimization, classical optimization: single variable, multivariable optimization techniques, linear programming: simplex method, duality, transportation problems, non-linear programming: one dimensional minimization methods, unconstrained optimization, dynamic programming: development of dynamic programming, principle of optimality, practical aspects of optimization: reduced basic techniques, sensitivity of optimum solution to problem parameters, modern optimization techniques.

Reference Books :
1. R. Fletcher, "Practical Optimization", Second edition, John Wiley and Sons, New York, 1987.
2. S. S. Rao, "Engineering Optimization-Theory and practice", Fourth edition, Wiley Easter Publications, January 2009.
3. K. V. Mital and C. Mohan, "Optimization Methods in Operations Research and System Analysis", New age International Publishers, Third edition, 1996.

MICROCOMPUTER CONTROLLED DRIVES
EEMD204B

Course Outcomes :
Application of digital controllers in electrical drives

Course Contents:
DC Drives- Converters, Microcontroller hardware circuit, Performance characteristics of DC drive. Chopper fed DC Drives, hardware, circuits and waveforms. Performance Characteristic of
AC Drives - Description and Performance behavior of 3-phase IM drive, Microcomputercontrolled inverter fed AC drive Waveforms for 1-phase, 3-phase non PWM and 3-phase PWMinverter fed induction drives, Sampling techniques for PWM inverter. Mathematical modeling offrequency controlled induction drive, mathematical model of the system for steady state anddynamic behavior, Study of stability based on the dynamic model of the system.Close loop control of microcomputer based Drives.

Reference Books:
1. Dubey G.K., Power semiconductor controlled drives, Prentiee-HALL, 1989
2. Bose B.K., Power electronics and variable frequency drives, IEEE Press, 1997
3. Bose B.K, Microcomputer control of power electronics and drive, IEEE Publications U.S., 1st June 1987
4. V. Subramanyam, Thyristor control of Electronic drive, McGraw Hill Education, 16 December 1987
5. Bose B.K, Adjustable AC drive
6. Leonard W, Control of electric drives, 3rd edition, Springer, September 21, 2001

COMPUTER AIDED DESIGN OF ELECTRICAL MACHINE
EEMD 204C

Course Outcome
I. Explane & analysis of time-varying and spatially dependant quantities of electric machines leading to better design.
II. Study MATLAB software for the analysis.

Course Contents:

Computer aided design- different approaches- analysis and synthesis methods- Hybrid method-Feasible design-Design optimization- general procedure for optimization-mathematical formulation of the objective function- Different objective functions-Non-linear constrained optimization techniques for design of electrical equipment- Exterior penalty function techniques-Geometric programming- comparison-Torque produced in electric machines -Steady state performance of induction machines, synchronous machines and commutator machines-Effect of flux harmonics-single phase induction machines-Transient phenomena in electric machines-Transformer design- Design considerations-core section and yoke section design- multistep core design-computation of step dimension for optimum fill-Design of insulation and windings-Example case for computerized design.

Reference Books:

1. P. S. Bhimbra, M Ramamoorthy, *'Computer aided Design of Electrical Equipments'*, Affiliated East West Press
2. A. K Sawhney , *_A Course in Electrical Machine Design"*
3. S K Sen, *'Principles of Electrical Machine Design* '-.Oxford and 1BH Publishing Co.
4. Matlab Reference Manual

FINITE ELEMENT METHODS OF ELECTRICAL MACHINES
EEMD205A

Course Outcome

I. Understand the basic electromagnetic field equations and the problem formulation for CAD applications.
II. Knowledge about Finite Element Method as applicable for Electrical Engineering.
III. Apply Finite Element Method for the design of different Electrical apparatus.

Course Contents:

Need for Field Analysis based design- Recent Trends Mathematical Formulation of Field Problems- Development of Torque/Force- Electromagnetic Field Equations - Magnetic Vector/Scalar Potential - Electrical Vector/Scalar Potential- Inductances - Maxwell Equations - Laplace and Poissons Equations- Philosophy of FEM- Differential/Integral Equations - Finite Difference Method - Finite Element Method- boundary conditions- Elements of CAD Systems - Preprocessing - Modeling - meshing - Material Properties - Boundary Conditions - Setting up Solutions- The electric field-finite element analysis

Reference Books:

1. SJ.Salon, Kluwer , ^Finite Element Analysis of Electrical Machines', Academic Pub;ishers, London
2. Krishna Moorthy C. S., An Introduction to Computer Aided Electromagnetic Analysis,Vector Field Finite Element Analysis *
3. Peter Silvester. Ronald L Ferrari. "Finite Elements for Electrical Engineers', Cambridge University Press.
4. S. Ratnajeevan H. Hoole , 'Computer Aided analysis and design of electromagnetics devices' Elsevier, Newyork.
5. D.A.Lowther and P.P.Silvester , 'Computer Aided design in Magnetics\ Springer Verlag, Newyork

SMART GRID TECHNOLOGIES
EEMD205B

Course Outcome: After undergoing the course, the students would get acquainted with the smart
technologies, smart meters and power quality issues in smart grids.

Course Outcome:
Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, Concept of Resilient & Self Healing Grid, Present development & International policies in
Smart Grid, Diverse perspectives from experts and global Smart Grid initiatives.Smart energy resources, Smart substations, Wide area monitoring, Protection and control,Phasor Measurement Unit (PMU), Intelligent Electronic Devices(IED) & their application formonitoring & protection Distribution systems: DMS, Volt/VAR control, Fault Detection, Isolationand service restoration, Outage management, Phase Shifting Transformers.Plug in Hybrid Electric Vehicles (PHEV). Introduction to Smart Meters, Advanced Meteringinfrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs inthe smart grid. Power Quality Conditioners for Smart Grid, Web based Power Qualitymonitoring, IP based Protocols, Cyber Security for Smart Grid.

Reference Books:
1. StuartBorlase, „SmartGrid:Infrastructure,Technologyand Solutions", CRC Press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, „Smart Grid: Technology and Applications",Wiley ,2012.
3. Vehbi C. Güngör, DilanSahin, TaskinKocak, SalihErgüt, ConcettinaBuccella, Carlo Cecati, and Gerhard P. Hancke, „Smart Grid Technologies: Communication Technologies and Standards" IEEE Transactions On Industrial Informatics,Vol. 7, No.4, November 2011.
4. Xi Fang, SatyajayantMisra, GuoliangXue, and Dejun Yang „Smart Grid – The New andImproved Power Grid: A Survey", IEEE Transaction on Smart Grids, 2011.

EHV AC & DC TRANSMISSION
EEMD205C

Course Outcomes: Application of power electronics and control in EHV AC & DC Systems
Course Content :
Long line theory, corona power loss and audible noise. Reactive Power compensation of EHV
AC lines, FACTs devices, Sequential impedances of AC systems EHVAC transmissionovervoltages, insulation design of lightning and switching over voltages. High voltage testing ofAC equipments, Comparison of EHV AC & DC transmission HVDC system configuration andcomponents conversion and inversion, Analysis of three phase bridge converter andPerformance equations, Control of HVDC system, Principle of DC link control, current andExtinction angle control, Transmission power control, alternative inverter control modes,Harmonics and AC/DC filters, Interaction responses to DC and AC system faults, Modelling ofHVDC system.

Reference Books:
1. Begemudre R.D., "EHVAC Transmission Engineering" – Willy Eastern Ltd.
2. P.Kundur "Power System Stability and Control" - McGraw Hill Publication.
3. Arrillaga J., "HVDC Transmission" - Peter Peregrinus Pub.
4. Rao S., "EHV AC & HVDC Transmission Systems" - Khanna Pub.
5. Padiyar K.R., "HVDC Power Transmission Systems" – Willy Eastern Ltd.