AFFILIATED INSTITUTIONS

ANNA UNIVERSITY, CHENNAI

REGULATIONS - 2009

CURRICULUM AND SYLLABUS I SEMESTER & ELECTIVES

M.E.HIGH VOLTAGE ENGINEERING

SEMESTER I

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	MA9314	Applied Mathematics for Electrical Engineers	3	1	0	4
2.	HV9311	Electromagnetic Field Computation and Modelling	3	1	0	4
3.	HV9312	High Voltage Generation and Measurement	3	0	0	3
4.	HV9313	Electrical Transients in Power System	3	0	0	3
5.	HV9314	Insulation Technology	3	0	0	3
6.	E1	Elective I	3	0	0	3
		TOTAL	**18**	**2**	**0**	**20**

ELECTIVES FOR M.E HIGH VOLTAGE ENGINEERING

SEMESTER I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1.	CO9012	System Theory	3	0	0	3
2.	PE9011	Analysis of Electrical machines	3	0	0	3
3.	ET9011	Advanced Digital System design	3	0	0	3

MA 9314 APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS **L T P C**
3 1 0 4

1. **ADVANCED MATRIX THEORY:** **9**
Eigen-values using QR transformations – Generalized eigen vectors – Canonical forms – Singular value decomposition and applications – Pseudo inverse – Least square approximations.

2. **LINEAR PROGRAMMING** **9**
Formulation – Graphical Solution – Simplex Method – Two Phase Method – Transportation and Assignment Problems.

3 .**ONE DIMENSIONAL RANDOM VARIABLES** **9**
Random variables - Probability function – moments – moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Function of a Random Variable.

4. **QUEUEING MODELS** **9**
Poisson Process – Markovian queues – Single and Multi Serve r Models – Little's formula – Machine Interference Model – Steady State analysis – Self Service queue.

5. **COMPUTATIONAL METHODS IN ENGINEERING** **9**
Boundary value problems for ODE – Finite difference methods – Numerical solution of PDE – Solution of Laplace and Poisson equations – Liebmann's iteration process – Solution of heat conduction equation by Schmidt explicit formula and Crank-Nicolson implicit scheme – Solution of wave equation.

L +T: 45+15 = 60

BOOKS FOR REFERENCE:

1. Bronson, R., Matrix Operation, Schaum's outline series, McGraw Hill, New York, (1989).
2. Taha, H. A., Operations Research: An Introduction, Seventh Edition, Pearson Education Edition, Asia, New Delhi (2002).
3. R. E. Walpole, R. H. Myers, S. L. Myers, and K. Ye, Probability and Statistics for Engineers & Scientists, Asia, 8th Edition, (2007).
4. Donald Gross and Carl M. Harris, Fundamentals of Queueing theory, 2nd edition, John Wiley and Sons, New York (1985).
5. Grewal, B.S., Numerical methods in Engineering and Science, 7th edition, Khanna Publishers, 200

HV 9311 ELECTROMAGNETIC FIELD COMPUTATION AND MODELLING **L T P C**
3 1 0 4

1. INTRODUCTION **9**

Review of basic field theory – electric and magnetic fields – Maxwell's equations – Laplace, Poisson and Helmoltz equations – principle of energy conversion – force/torque calculation – Electro thermal formulation.

2. SOLUTION OF FIELD EQUATIONS I **9**

Limitations of the conventional design procedure, need for the field analysis based design, problem definition , solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods- Finite Difference Method.

3. SOLUTION OF FIELD EQUATIONS II **9**

Finite element method (FEM) – Differential/ integral functions – Variational method – Energy minimization – Discretisation – Shape functions –Stiffness matrix –1D and 2D planar and axial symmetry problem.

4. FIELD COMPUTATION FOR BASIC CONFIGURATIONS **9**

Computation of electric and magnetic field intensities– Capacitance and Inductance – Force, Torque, Energy for basic configurations.

5. DESIGN APPLICATIONS **9**

Insulators- Bushings – Cylindrical magnetic actuators – Transformers – Rotating machines.

L=45: T=15, Total =60 PERIODS

REFERENCES

1. K.J.Binns, P.J.Lawrenson, C.W Trowbridge, "The analytical and numerical solution of Electric and magnetic fields", John Wiley & Sons, 1993.
2. Nathan Ida, Joao P.A.Bastos , "Electromagnetics and calculation of fields", Springer-Verlage, 1992.
3. Nicola Biyanchi , "Electrical Machine analysis using Finite Elements", Taylor and Francis Group, CRC Publishers, 2005.
4. S.J Salon, "Finite Element Analysis of Electrical Machines." Kluwer Academic Publishers, London, 1995, distributed by TBH Publishers & Distributors, Chennai, India
5. User manuals of MAGNET, MAXWELL & ANSYS software.
6. Silvester and Ferrari, "Finite Elements for Electrical Engineers" Cambridge University press, 1983.

HV 9312 HIGH VOLTAGE GENERATION AND MEASURMENT L T P C
3 0 0 3

1. GENERATION OF DIRECT VOLTAGES 9

Generation and transmission of electric energy – voltage stress – testing voltages-AC to DC conversion – single phase rectifier circuits – cascaded circuits – voltage multiplier circuits – Cockroft-Walton circuits – voltage regulation – ripple factor – Design of HVDC generator – Vande-Graff generator.

2. GENERATION OF ALTERNATING VOLTAGES 9

Testing transformer – single unit testing transformer, cascaded transformer – equivalent circuit of cascaded transformer – series resonance circuit – resonant transformer – voltage regulation.

3. GENERATION OF IMPULSE VOLTAGES 9

Marx generator – Impulse voltage generator circuit – analysis of various impulse voltage generator circuits – multistage impulse generator circuits – Switching impulse generator circuits – impulse current generator circuits – generation of non-standard impulse voltages and nanosecond pulses.

4. MEASURMENT OF HIGH VOLTAGES 9

Peak voltage measurements by sphere gaps – Electrostatic voltmeter – generating voltmeters and field sensors – Chubb-Fortescue method – voltage dividers and impulse voltage measurements-

5. GENERATION AND MEASUREMENT OF IMPULSE CURRENTS 9

Generation of impulse currents, measurement of impulse currents – Resistive shunts , measurement using magnetic coupling - Fast digital transient recorders for impulse measurements.

TOTAL : 45 PERIODS

REFERENCES

1. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005
2. Dieter Kind, Kurt Feser, “High Voltage Test Techniques”, SBA Electrical Engineering Series, New Delhi, 1999.
3. Naidu M S and Kamaraju V, “High Voltage Engineering”, Tata McGraw-hill Publishing Company Ltd., New Delhi, 2004.
4. Gallagher, T.J., and Permain, A., “High Voltage Measurement, Testing and Design”, John Wiley Sons, New York, 1983.
5. R.Mazen Abdel-Salam, Hussein Anis, Ahdab El-Morshedy, Roshdy Radwan, “High Voltage Engineering Theory and Practice” Second Edition, Revised and Expanded, Marcel Dekker, Inc., New York, 2000.
6. N.H.Malik, A.A.Al_Arainy, M.I.Qureshi, “ Electrical Insulation in Power Systems”, marcel Dekker,Inc., New York 1988.
7. Adolf J. Schwab, “High Voltage Measurement Techniques”, M.I.T Press, 1972.

HV 9313 ELECTRICAL TRANSIENTS IN POWER SYSTEMS L T P C
3 0 0 3

1. TRAVELLING WAVES ON TRANSMISSION LINE 9

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour 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 - Behaviour 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.

TOTAL : 45 PERIODS

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. 1-20.

HV 9314 **INSULATION TECHNOLOGY** **L T P C**
3 0 0 3

1. GENERAL PROPERTIES OF INSULATING MATERIALS 9

Requirements of insulating materials – electrical properties – molecular properties of dielectrics – dependence of permittivity on temperature, pressure, humidity and voltage, permittivity of mixtures, practical importance of permittivity – behavior of dielectric under alternating fields – complex dielectric constants – bipolar relaxation and dielectric loss, dielectric strength.

2. BREAKDOWN MECHANISMS IN GASEOUS DIELECTRICS 9

Behaviour of gaseous dielectrics in electric fields – gaseous discharges – different ionization processes – effect of electrodes on gaseous discharge – Townsend's theory, Streamer theory – electronegative gases and their influence on gaseous discharge – Townsend's criterion for spark breakdown, gaseous discharges in non-uniform fields - breakdown in vacuum insulation.

3. BREAKDOWN MECHANISMS IN SOLID DIELECTRICS 9

Intrinsic breakdown of solid dielectrics – electromechanical breakdown-Streamer breakdown, thermal breakdown and partial discharges in solid dielectrics - electrochemical breakdown – tracking and treeing – classification of solid dielectrics, composite insulation and its mechanism of failure.

4. BREAKDOWN MECHANISMS IN LIQUID DIELECTRICS 9

Liquids as insulators, conduction and breakdown in pure and commercial liquids, Cryogenic insulation.

5. APPLICATION OF INSULATING MATERIALS 9

Application of insulating materials in transformers. rotating machines, circuit breakers, cables, power capacitors and bushings.

TOTAL : 45 PERIODS

REFERENCES

1. Adrinaus, J.Dekker, "Electrical Engineering Materials", Prentice Hall of India Pvt. Ltd., New Delhi, 1979.
2. Alston, L.L, "High Voltage Technology", Oxford University Press, London, 1968 (B.S Publications, First Indian Edition 2006)
3. Kuffel, E., Zaengl, W.S. and Kuffel J., "High Voltage Engineering Fundamentals", Elsvier India Pvt. Ltd, 2005
4. Dieter Kind and Hermann Karner, "High Voltage Insulation Technology", 1985. (Translated from German by Y. Narayana Rao, Friedr. Vieweg & Sohn, Braunschweig,).
5. M.S Naidu, V.Kamaraj, "High Voltage Engineering", Tata Mc Graw-Hill Publishing Company Ltd., New Delhi, 2004.
6. V.Y.Ushakov, "Insulation of High Voltage Equipment", Springer ISBN.3-540-20729-5, 2004.

CO 9012 **SYSTEM THEORY** **L T P C**
3 0 0 3

1. STATE VARIABLE REPRESENTATION **9**

Introduction-Concept of State-State equation for Dynamic Systems-Time invariance and linearity-Nonuniqueness of state model-State Diagrams-Physical System and State Assignment.

2. SOLUTION OF STATE EQUATION **9**

Existence and uniqueness of solutions to Continuous-time state equations-Solution of Nonlinear and Linear Time Varying State equations-Evaluation of matrix exponential-System modes-Role of Eigenvalues and Eigenvectors.

3. CONTROLLABILITY AND OBSERVABILITY **9**

Controllability and Observability-Stabilizability and Detectability-Test for Continuous time Systems- Time varying and Time invariant case-Output Controllability-Reducibility-System Realizations.

4. STABILTY **9**

Introduction-Equilibrium Points-Stability in the sense of Lyapunov-BIBO Stability-Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems-Krasovskii and Variable-Gradiant Method.

5. MODAL CONTROL **9**

Introduction-Controllable and Observable Companion Forms-SISO and MIMO Systems-The Effect of State Feedback on Controllability and Observability-Pole Placement by State Feedback for both SISO and MIMO Systems-Full Order and Reduced Order Observers.

TOTAL : 45 PERIODS

REFERENCES:

1. M. Gopal, “Modern Control System Theory”, New Age International, 2005.
2. K. Ogatta, “Modern Control Engineering”, PHI, 2002.
3. John S. Bay, “Fundamentals of Linear State Space Systems”, McGraw-Hill, 1999.
4. D. Roy Choudhury, “Modern Control Systems”, New Age International, 2005.
5. John J. D’Azzo, C. H. Houpis and S. N. Sheldon, “Linear Control System Analysis and Design with MATLAB”, Taylor Francis, 2003.
6. Z. Bubnicki, ”Modern Control Theory”, Springer, 2005.

PE 9011 ANALYSIS OF ELECTRICAL MACHINES L T P C
3 0 0 3

1. PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9

General expression of stored magnetic energy, co-energy and force/ torque – example using single and doubly excited system –Calculation of air gap mmf and per phase machine inductance using physical machine data.

2. REFERENCE FRAME THEORY 9

Static and rotating reference frames – transformation of variables – reference frames – transformation between reference frames – transformation of a balanced set – balanced steady state phasor and voltage equations – variables observed from several frames of reference.

3. DC MACHINES 9

Voltage and toque equations – dynamic characteristics of permanent magnet and shunt DC motors – state equations - solution of dynamic characteristic by Laplace transformation.

4. INDUCTION MACHINES 9

Voltage and toque equations – transformation for rotor circuits – voltage and toque equations in reference frame variables – analysis of steady state operation – free acceleration characteristics – dynamic performance for load and torque variations – dynamic performance for three phase fault – computer simulation in arbitrary reference frame.

5. SYNCHRONOUS MACHINES 9

Voltage and Torque Equation – voltage Equation in arbitrary reference frame and rotor reference frame – Park equations - **rotor angle and angle between rotor** – steady state analysis – dynamic performances for torque variations- dynamic performance for three phase fault – transient stability limit – critical clearing time – computer simulation.

TOTAL : 45 PERIODS

TEXT BOOKS

1. Paul C.Krause, OlegWasyzczuk, Scott S, Sudhoff, “Analysis of Electric Machinery and Drive Systems”, IEEE Press, Second Edition.
2. R.Krishnan, “Electric Motor Drives, Modeling, Analysis and Control” , Prentice Hall of India, 2002

REFERENCES

1. Samuel Seely, “ Eletomechanical Energy Conversion”, Tata McGraw Hill Publishing Company,
2. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, “ Electric Machinery”, Tata McGraw Hill, 5th Edition, 1992

ET 9011 ADVANCED DIGITAL SYSTEM DESIGN L T P C
3 0 0 3

AIM

To expose the students to the fundamentals of digital logic based system design**.**

OBJECTIVES

To impart knowledge on

i. Basics on Synchronous & Async digital switching design.
ii. Design & realisation of error free functional blocks for digital systems

1. SEQUENTIAL CIRCUIT DESIGN 9

Analysis of Clocked Synchronous Sequential Networks (CSSN) Modelling of CSSN – State Stable Assignment and Reduction – Design of CSSN – Design of Iterative Circuits – ASM Chart – ASM Realization, Design of Arithmetic circuits for Fast adder- Array Multiplier.

2. ASYNCHRONOUS SEQUENTIAL CIRCUIT DESIGN 9

Analysis of Asynchronous Sequential Circuit (ASC) – Flow Table Reduction – Races in ASC – State Assignment Problem and the Transition Table – Design of ASC – Static and Dynamic Hazards – Essential Hazards – Data Synchronizers – Designing Vending Machine Controller – Mixed Operating Mode Asynchronous Circuits.

3. FAULT DIAGNOSIS AND TESTABILITY ALGORITHMS 9

Fault Table Method – Path Sensitization Method – Boolean Difference Method – Kohavi Algorithm – Tolerance Techniques – The Compact Algorithm – Practical PLA's – Fault in PLA – Test Generation – Masking Cycle – DFT Schemes – Built-in Self Test.

4. SYNCHRONOUS DESIGN USING PROGRAMMABLE DEVICES 9

Programming Techniques -Re-Programmable Devices Architecture- Function blocks, I/O blocks, Interconnects, Realize combinational, Arithmetic, Sequential Circuit with Programmable Array Logic; Architecture and application of Field Programmable Logic Sequence.

5. NEW GENERATION PROGRAMMABLE LOGIC DEVICES 9

Foldback Architecture with GAL, EPLD, EPLA , PEEL, PML; PROM – Realization State machine using PLD – FPGA – Xilinx FPGA – Xilinx 2000 - Xilinx 3000

TOTAL : 45 PERIODS

REFERENCES:

1. Donald G. Givone, "Digital principles and Design", Tata McGraw Hill 2002.
2. Stephen Brown and Zvonk Vranesic, "Fundamentals of Digital Logic with VHDL Deisgn", Tata McGraw Hill, 2002
3. Mark Zwolinski, "Digital System Design with VHDL", Pearson Education, 2004
4. Parag K Lala, "Digital System design using PLD", BS Publications, 2003
5. John M Yarbrough, "Digital Logic applications and Design", Thomson Learning, 2001
6. Nripendra N Biswas, "Logic Design Theory", Prentice Hall of India, 2001

7. Charles H. Roth Jr., “Fundamentals of Logic design”, Thomson Learning, 2004.