NATIONAL ENGINEERING COLLEGE

(An Autonomous Institution – Affiliated to Anna University Chennai)

K.R.NAGAR, KOVILPATTI – 628 503

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REGULATIONS - 2015

DEPARTMENT OF

ELECTRICAL AND ELECTRONICS ENGINEERING

CURRICULUM AND SYLLABI OF

M.E. – HIGH VOLTAGE ENGINEERING

SEMESTER – I

S. No.	Course Category	Course Code	Course Title	L	T	P	C	Question pattern⊕
THEORY COURSES								
1.	SFC	15HE11C	Higher Engineering Mathematics@	3	2	0	4	B
2.	PCC	15HE12C	Field Computation and Modeling of Electromagnetic Devices	3	2	0	4	B
3	PCC	15HE13C	Elements of High Voltage Engineering	3	0	0	3	B
4.	PCC	15HE14C	Dielectric Engineering	3	0	0	3	B
5.	PCC	15HE15C	High Voltage Equipments	3	0	0	3	B
6.	PEC		Elective-I	3	0	0	3	
PRACTICAL COURSES								
7.	PCC	15HE16C	High Voltage Laboratory-I	0	0	4	2	
			Total	**18**	**4**	**4**	**22**	

SEMESTER – II

S. No.	Course Category	Course Code	Course Title	L	T	P	C	Question pattern⊕
THEORY COURSES								
1.	PCC	15HE21C	Electrical Power System Transients	3	0	0	3	B
2.	PCC	15HE22C	High Voltage Protection and Switchgear	3	0	0	3	B
3.	PCC	15HE23C	Design of Insulations for High Voltage Equipments	3	2	0	4	A
4.	PCC	15HE24C	Extra High Voltage Power Transmission	3	2	0	4	B
5.	PEC		Elective-II	3	0	0	3	
PRACTICAL COURSES								
6.	PCC	15HE25C	High Voltage Laboratory-II	0	0	4	2	
7.	PCC	15HE26C	Research Paper and Patent Review – Seminar	0	0	4	2	
			Total	**15**	**4**	**8**	**21**	

SFC - Special Foundation Course, PCC – Programme Core Course, PEC – Programme Elective Course, OEC – Open Elective Course
***Common to CS, HVE and C&I, @ Common to HVE and C&I, £ Common to C&N and HVE

SEMESTER – III

S. No.	Course Category	Course Code	Course Title	L	T	P	C	Question pattern⊕
THEORY COURSES								
1.	PEC		Elective-III	3	0	0	3	
2.	PEC		Elective-IV	3	0	0	3	
3.	PEC		Elective-V	3	0	0	3	
4.	OEC		Elective-VI	3	0	0	3	
PRACTICAL COURSES								
5.	PCC	15HE31C	Project Work Phase-I	0	0	12	6	
			Total	12	0	12	18	

SEMESTER – IV

S. No.	Course Category	Course Code	Course Title	L	T	P	C	Question pattern⊕
PRACTICAL COURSES								
1.	PCC	15HE41C	Project Work Phase-II	0	0	24	12	
			TOTAL	0	0	24	12	

SFC - Special Foundation Course, PCC – Programme Core Course, PEC – Programme Elective Course, OEC – Open Elective Course
*****Common to CS, HVE and C&I, @ Common to HVE and C&I, £ Common to C&N and HVE

PROGRAMME ELECTIVE COURSES

S. No.	Course Category	Course Code	Course Title	L	T	P	C	Question pattern⊕
1.	PEC	15HE01E	Electromagnetic Interference and Electromagnetic Compatibility	3	0	0	3	A
2.	PEC	15HE02E	Pulse Power Engineering	3	0	0	3	A
3.	PEC	15HE03E	Advanced Electromagnetic Fields	3	0	0	3	B
4.	PEC	15HE04E	Pollution Performance of Power Apparatus and Systems	3	0	0	3	A
5.	PEC	15HE05E	High Voltage Direct Current Transmission	3	0	0	3	B
6.	PEC	15HE06E	Collision Phenomenon	3	0	0	3	A
7.	PEC	15HE07E	Advanced Topics in High Voltage Engineering	3	0	0	3	A
8.	PEC	15HE08E	High Voltage Fields	3	0	0	3	B
9.	PEC	15HE09E	Flexible AC Transmission Systems	3	0	0	3	B
10.	PEC	15HE10E	Power Quality	3	0	0	3	B
11.	PEC	15HE11E	Restructured Power Systems	3	0	0	3	B
12.	PEC	15HE12E	Power System Planning and Reliability	3	0	0	3	B
13.	PEC	15HE13E	Power System Analysis	3	0	0	3	B
14.	PEC	15HE14E	Power System Operation and Control	3	0	0	3	B
15.	PEC	15HE15E	Reactive Power Compensation and Management	3	0	0	3	B
16.	PEC	15HE16E	Power Electronics for Renewable Energy Systems	3	0	0	3	B
17.	PEC	15HE17E	Modern Rectifiers and resonant Converters	3	0	0	3	B
18.	PEC	15HE18E	Analysis of Power Converters	3	0	0	3	B
19.	PEC	15HE19E	Power Electronics in Power Systems	3	0	0	3	B
20.	PEC	15HE20E	Control of Electric Drives	3	0	0	3	B
21.	PEC	15HE21E	Computer Aided Design of Power Electronics Circuits	3	0	0	3	B
22.	PEC	15HE22E	Advanced Electrical Drives	3	0	0	3	B
23.	PEC	15HE23E	Soft Computing Techniques@	3	0	0	3	A
24.	PEC	15HE24E	Advanced Digital Signal Processing*	3	0	0	3	B
25.	PEC	15HE25E	Evolutionary Computing£	3	0	0	3	B
26.	PEC	15HE26E	Advanced Digital System Design@	3	0	0	3	B
27.	PEC	15HE27E	Design of Embedded Systems@	3	0	0	3	B
28.	PEC	15HE28E	Applications of MEMS Technology	3	0	0	3	B
29.	PEC	15HE29E	Microcontroller and DSP based System Design	3	0	0	3	B
30.	PEC	15HE30E	Optimization Techniques	3	0	0	3	B
31.	PEC	15HE31E	Wind Energy Conversion Systems	3	0	0	3	B
32.	PEC	15HE32E	Energy management	3	0	0	3	B
33.	PEC	15HE33E	Fundamentals of Nano Technology	3	0	0	3	B
34.	PEC	15HE34E	System Theory@	3	0	0	3	B
35.	PEC	15HE35E	PC based Instrumentation System Design@	3	0	0	3	B

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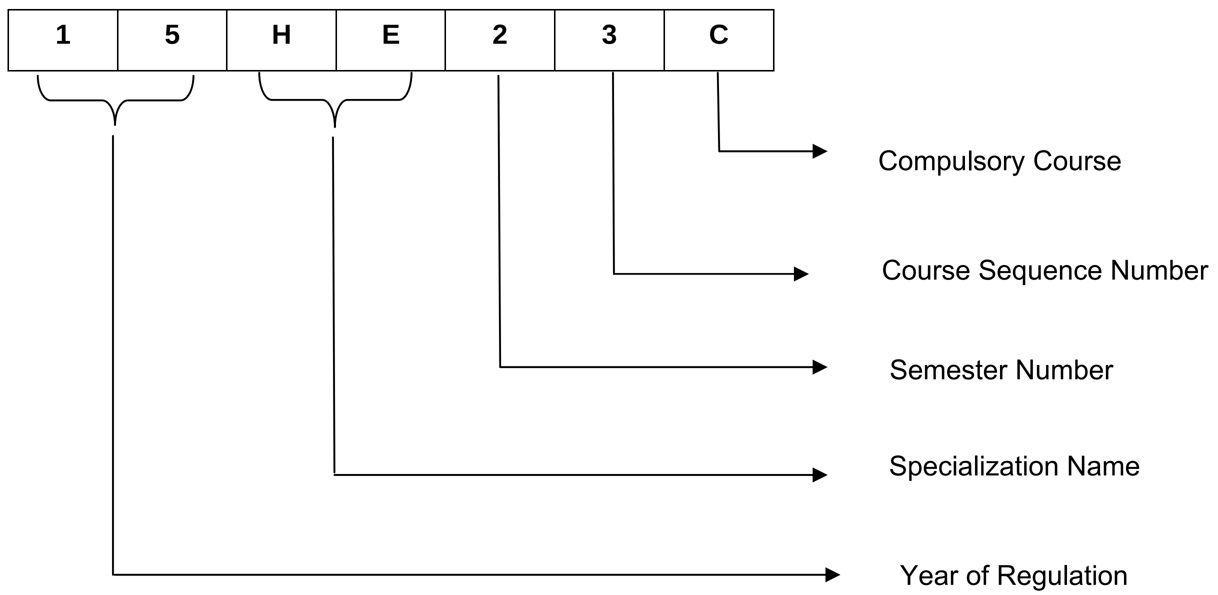
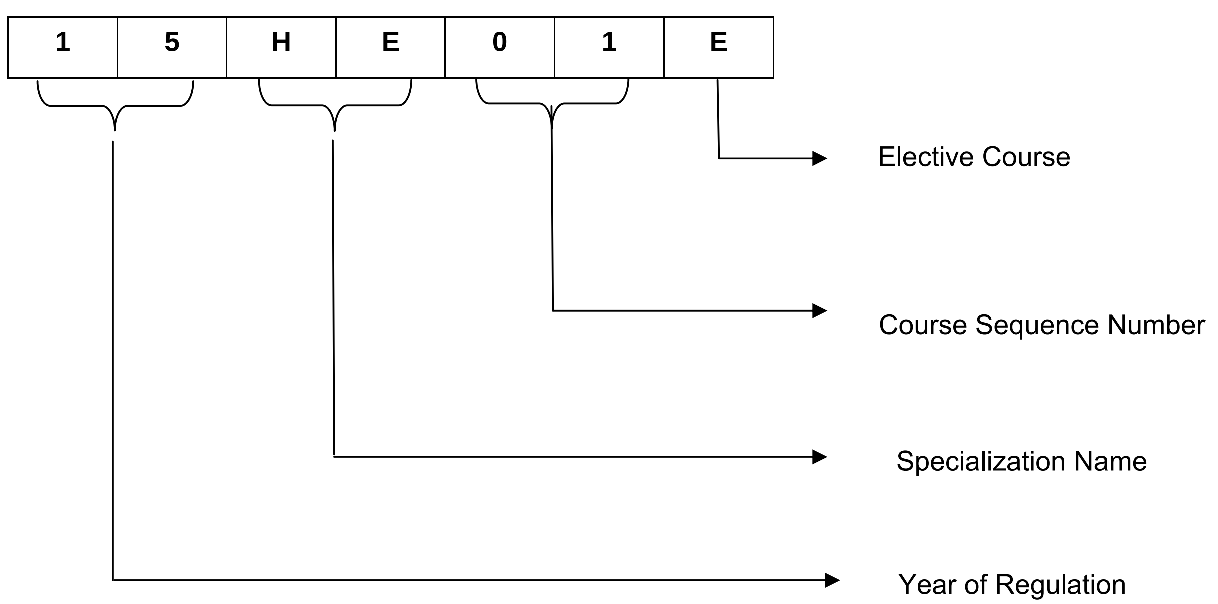
S. No.	Course Category	Course Code	Course Title	L	T	P	C	Question pattern⊕
36.	PEC	15HE36E	Analysis of Electrical Machines	3	0	0	3	A
37.	PEC	15HE37E	Special Electrical Machines	3	0	0	3	B
38	PEC	15HE38E	Condition Monitoring of High Voltage Power Apparatus	3	0	0	3	A
39.	OEC		Courses offered by other PG programmes	3	0	0	3	

⊕

Question pattern	1 mark	2 marks	4 marks	10 marks	12 marks	16 marks	20 marks	Total
A	-	-	-	-	--	-	1 Qn Compulsory & 4 Qns (either or type)	100
B	-	10	-	-	--	1 Qn Compulsory & 4 Qns (either or type)	--	100
C	10	-	10 out of 12	1 Qn Compulsory & 4 Qns (either or type)	--	--	--	100
D	10	10	5 out of 6	1 Qn Compulsory & 4 Qns (either or type)	--	--	--	100
E	-	10	5 out of 6	-	1 Qn Compulsory & 4 Qns (either or type))	--	--	100

FORMAT FOR COURSE CODE





15HE11C HIGHER ENGINEERING MATHEMATICS **L T P C**
(Common to HVE and C&I) **3 2 0 4**

COURSE OUTCOMES

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

CO 1 : learn the concepts of matrix theory. (K1)
CO 2 : understand simplex method, two phase method and graphical solution in linear programming. (K2)
CO 3 : learn moment generating functions and one dimensional random variables. (K1)
CO 4 : understand queueing models and computation methods in engineering. (K2)

UNIT I ADVANCED MATRIX THEORY 15

Eigen-values using QR transformations – Generalized eigen vectors – Canonical forms – Singular value decomposition and applications – Pseudo inverse – Least square approximations.

UNIT II LINEAR PROGRAMMING 15

Formulation – Graphical Solution – Simplex Method – Two Phase Method – Transportation and Assignment Problems.

UNIT III ONE DIMENSIONAL RANDOM VARIABLES 15

Random variables - Probability function – moments – moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions.

UNIT IV QUEUEING MODELS 15

Poisson Process – Markovian queues – Single and Multi Server Models – Little's formula – Machine Interference Model – Steady State analysis – Self Service queue.

UNIT V COMPUTATIONAL METHODS IN ENGINEERING 15

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: 45 T: 30 TOTAL: 75 PERIODS

REFERENCES

1. Bronson,R., "Matrix Operation, Schaum's outline series", McGraw Hill, New York, 1989.
2. Taha, H. A., "Operations Research: An Introduction", 7th 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", 8th Edition, Asia, 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, 2000.

15HE12C FIELD COMPUTATION AND MODELING OF ELECTROMAGNETIC DEVICES

L T P C
3 2 0 4

COURSE OUTCOMES

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

CO 1: recall the basic concepts in electric and magnetic fields. (K1)
CO 2: choose the new techniques to find the solutions of electro static boundary value problems. (K6)
CO 3: improve the new techniques to achieve the accurate results. (K6)
CO 4: determine and find the various parameters of field configurations. (K5)
CO 5: model the various electrical apparatus. (K3)

UNIT I INTRODUCTION 15

Review of basic field theory – Electric and magnetic fields – Maxwell's equations – Laplace, Poisson and Helmholtz equations – Principle of energy conversion – Force/torque calculation – Electro Thermal formulation.

UNIT II SOLUTIONS OF FIELD EQUATIONS I 15

Limitations of the conventional design procedure need for the field analysis based design – Problem definition and solution by analytical methods - Direct integration method – Variable separable method – Method of images – Solution by numerical methods – Finite Difference Method.

UNIT III SOLUTIONS OF FIELD EQUATIONS II 15

Finite element method (FEM) – Differential/ integral functions – Variational method – Energy minimization – Discretisation – Shape functions –Stiffness matrix.

UNIT IV FIELD COMPUTATION FOR BASIC CONFIGURATIONS 15

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

UNIT V DESIGN APPLICATIONS 15

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

L: 45 T: 30 TOTAL: 75 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, Second Edition, 2002.
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, Third Edition, 1996.
7. Marcel Dector "Finite Element Analysis of Electrical Machines." Tata McGraw-Hill Edition 2003.
8. William Hayt, "Engineering Electromagnetics" Tata McGraw-Hill Edition 2012.
9. Mathew Sadiku,"Elements of Electromagnetics", Oxford University Press, Ninth Edition, 2007.

15HE13C ELEMENTS OF HIGH VOLTAGE ENGINEERING

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO 1: identify the various methods for generation of HVAC. (K3)
CO 2: appraise the various types for generation of HVDC. (K5)
CO 3: design the generator circuits for impulse voltage and current. (K6)
CO 4: identify the suitable measurement techniques of HVAC, HVDC and impulse voltages and currents. (K3)
CO 5: coordinate the various standards for testing of HV equipments. (S4)

UNIT I GENERATION OF HIGH AC VOLTAGES 9

Testing transformer – Single unit testing transformer - Cascaded transformer – Resonant transformer.

UNIT II GENERATION OF HIGH DC VOLTAGES 9

AC to DC conversion – Single phase rectifier circuits – Cascaded circuits – Voltage multiplier circuits – Cockroft-Walton circuits – Vande-Graff generator.

UNIT III GENERATION OF IMPULSE VOLTAGES AND CURRENTS 9

Marx generator – Impulse voltage generator circuit – Multistage impulse generator circuits – Switching impulse generator circuits – Impulse current generator circuits – Generation of non-standard impulse voltages and nanosecond pulses.

UNIT IV MEASURMENT OF HIGH VOLTAGES AND CURRENTS 9

Peak voltage measurements by sphere gaps – Electrostatic voltmeter – Generating voltmeters and field sensors – Chubb-Fortescue method – Voltage dividers and impulse voltage measurements – Measurement of impulse currents – Resistive shunts – Hall Generators and Faraday generators and their applications – Measurement using magnetic coupling – Fast digital transient recorders for impulse measurements.

UNIT V HIGH VOLTAGE TESTING METHODS 9

Testing of insulators, bushings, air break switches, isolators, circuit breakers, power transformers, voltage transformers, current transformers, surge diverters, cable – Testing methodology – Partial discharge measurements - PD equivalent model – PD quantities – Digital PD instruments and measurements – Artificial Pollution tests – Salt-fog method – Solid layer method.

L:45 TOTAL: 45 PERIODS

REFERENCES

1. Dieter Kind, Kurt Feser, “High Voltage Test Techniques”, SBA Electrical Engineering Series, New Delhi, 1999.
2. Naidu M.S. and Kamaraju V., “High voltage Engineering”, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2009.
3. Kuffel E., Zaengl W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India P Ltd, 2005.
4. Gallagher T.J. and Pearmain A., “High Voltage Measurements, Testing and Design”, John Willey&Sons, New York, 1983.
5. Judd M.D., Liyang and Ian BB Hunter, “PD Monitoring of Power Transformers using UHF Sensors” Vol.21, No.2, pp. 5-14, 2004.

15HE14C DIELECTRIC ENGINEERING **L T P C**
3 0 0 3

COURSE OUTCOMES

Upon completion of this course, students will be able to

CO 1: summarize the general properties of dielectric materials (K2)
CO 2: select the different dielectric materials in electrical equipments applications (K5)
CO 3: dissect the different breakdown mechanism in gaseous dielectrics (K4)
CO 4: perceive the various breakdown mechanisms in solid dielectrics (K5)
CO 5: appraise the conduction and breakdown mechanism in liquid dielectrics (K5)

UNIT I INTRODUCTION 9

Properties of dielectric material – Electric stress and electric strength – Estimation and control of electric stress – Brief overview of breakdown mechanisms – Polarisation mechanism – Different types of polarization, effect of polarization on permittivity – Dependence of permittivity on temperature, pressure, humidity and voltage – Permittivity of mixtures – Practical importance of permittivity.

UNIT II DIELECTRIC MATERIALS 9

Classification based on insulating materials and application – Application of insulating materials in transformers, rotating machines, circuit breakers, cables, power capacitors and bushings.

UNIT III BREAKDOWN IN GASES AND VACCUM 9

Basic ionization process – Townsend current growth equations – Townsend criterion for spark breakdown – Streamer mechanisms – Breakdown in electronegative gases – Time lags of spark breakdown – Paschen's law – Breakdown in non-uniform fields – Vacuum: Pre-breakdown conduction – Factors affecting the breakdown voltage – Frequency of applied voltage.

UNIT IV BREAKDOWN IN SOLIDS 9

Intrinsic breakdown – Electromechanical breakdown – Thermal breakdown – Chemical and electrochemical deterioration – Breakdown due to tracking and treeing – Partial discharges.

UNIT V ELECTRICAL CONDUCTION AND BREAKDOWN IN LIQUIDS 9

Pure liquids and commercial liquids – Purification – Natural conduction – Induced conduction – Process of conduction – Breakdown phenomena and electric strength of pure liquids – Breakdown of commercial liquids.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Adrinaus, Dekker J., "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", (Translated from German by NarayanaRao Y., Friedr. Vieweg&Sohn, Braunschweig), 1985.
5. Naidu M.S. and Kamaraju V., "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2009.
6. Ushakov V.Y., "Insulation of High Voltage Equipment", Springer, ISBN.3-540-20729- 5, 2004.

15HE15C HIGH VOLTAGE EQUIPMENTS

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO1: inspect the behavior of HV Power Transformer (K4)
CO2: illustrate the basic concepts of different types of cables and protection devices (K2)
CO3: identify the appropriate bushing techniques for high voltage applications (K3)
CO4: outline the basic concepts of circuit breakers (K2)
CO5: appraise the theory of Gas Insulated Substation (K5)

UNITI HIGH VOLTAGE POWER TRANSFORMER 9

Transformer insulation requirements – Dielectric strength and voltage conditions – Winding arrangements – Surge behavior – Behavior of liquid dielectric – Electrode surface phenomena – Gas evolution – Processing techniques – Construction of EHV transformer – Short circuit behavior.

UNIT II HIGH VOLTAGE CABLES AND HIGH PROTECTION DEVICES 9

Different types of cables – Paper insulated cables – XLPE cables – Gas-filled cables – Types, Working and applications of Insulators, Surge Diverter, Lighting Arrester, Disconnect switches.

UNIT III HIGH VOLTAGE BUSHINGS 9

Types – Non-condenser bushing – Condenser bushing – Bushing application for different equipments like Alternator, transformer, switchgear, wall bushing – Design of bushing and testing procedures.

UNIT IV HIGH VOLTAGE CIRCUIT BREAKERS 9

Arc interruption concept – Circuit making and breaking – Types – Airbreak, SF_6 and vacuum circuit breakers.

UNIT V GAS INSULATED SUBSTATION (GIS) 9

Comparison of GIS and air insulated substations – Design and layout of GIS – Description of various components of GIS - Advantages of GIS. appraise

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Anthony J. Pansini, “Electrical Transformers and Power Equipment”, 3rd Edition, Prentice Hall Publications, 1999.
2. Ruben D. Garzon, “High Voltage Circuit Breakers: Design and Applications”, 2nd Edition, Taylor and Francis Publications, 2005.
3. Nakanishi, “Switching Phenomena in High-Voltage Circuit Breakers”, Marcel – Dekker Inc, 1991.
4. M. S. Naidu, “Gas Insulated Substations”, L.K. International Publishing House Pvt. Ltd., 2008.
5. Colin Bayliss, Colin R. Bayliss, Brian J. Hardy, “Transmission and Distribution Electrical Engineering”, Elsevier Ltd., 2012.

15HE16C **HIGH VOLTAGE LABORATORY – I** **L T P C**
0 0 4 2

COURSE OUTCOMES

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

CO 1: tell the basic requirements and safety precautions (K1)

CO 2: analyze the various (electrical, thermal, mechanical and chemical) properties of liquid dielectrics (K4)

CO 3: perform the simulation of various impulse voltage generator circuits (S2)

CO 4: practice simulation software for designing various HV equipments (A2)

CO 5: design and analyze the different combinations of R, L and C of transient circuit (K6)

LIST OF EXPERIMENTS

1. Basics of Dielectrics Laboratory
2. Measurement of dielectric strength of liquid dielectric (Transformer Oil)
3. Measurement of Loss angle and resistivity of liquid dielectric (Transformer Oil)
4. Measurement of Flash point & Fire point of liquid dielectrics
5. Measurement of Viscosity of liquid dielectrics
6. Measurement of pH
7. Measurement of Conductivity of samples
8. Simulation of Lightning and Switching Impulse voltage generator
9. Simulation of RL,RC and RLC-DC transient circuit
10. FEM Simulation of different electrode configurations
11. FEM Simulation of single and composite dielectrics field distribution
12. FEM Simulations of Insulators

P: 60 TOTAL: 60 PERIODS

15HE21C ELECTRICAL POWER SYSTEM TRANSIENTS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: appraise the concept of travelling waves on transmission line (K5)
CO 2: evaluate the transient effects in power networks and components (K5)
CO 3: describe the mechanism of over voltages and its effects (A1)
CO 4: discuss the behavior of electrical equipments under transient conditions (A2)
CO 5: formulate the insulation coordination of different types of sub stations (A4)

UNIT I TRAVELLING WAVES ON TRANSMISSION LINE 9

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

UNIT II COMPUTATION OF POWER SYSTEM TRANSIENTS 9

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

UNIT III 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).

UNIT IV 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.

UNIT V INSULATION CO-ORDINATION 9

Principle of insulation coordination in Air Insulated Substation (AIS) and Gas Insulated Substation (GIS) – Insulation level – Statistical approach – Coordination between insulation and protection level – Overvoltage protective devices – Lightning arresters – Substation earthing.

L:45 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”, New Age International (P) Ltd., New Delhi, Second Edition, 2011
5. Naidu M S and Kamaraju V, “High Voltage Engineering”, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2009
6. IEEE Guide for safety in AC substation grounding IEEE Standard 80-2000.
7. Working Group 33/13-09, “Very fast transient phenomena associated with Gas Insulated System”, CIGRE, 33-13, pp. 1-20, 1988.

15HE22C HIGH VOLTAGE PROTECTION AND SWITCHGEAR L T P C
3 0 0 3

COURSE OUTCOMES

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

CO 1: summarize the various levels of insulation in power apparatus (K2)
CO 2: describe the circuit interruption techniques (A1)
CO 3: analyze the problems associated with circuit interruption by a circuit breaker (K4)
CO 4: discuss different types of circuit breakers (A2)
CO 5: explain about the testing of circuit breakers (A3)

UNIT I INTRODUCTION 9

Insulation of switchgear – Coordination between inner and external insulation – Insulation clearances in air, oil, SF_6 and vacuum – Bushing insulation – Solid insulating materials – Dielectric strength consideration.

UNIT II CIRCUIT INTERRUPTION 9

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 reclosing.

UNIT III SHORT CIRCUIT CALCULATIONS AND RATING OF CIRCUIT BREAKERS 9

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.

UNIT IV TYPES OF CIRCUIT BREAKERS 9

Classification of circuit breakers – Design, construction and operating principles of bulk oil, minimum oil, air blast, SF_6 and vacuum circuit breakers – Comparison of different types of circuit breakers.

UNIT V TESTING OF CIRCUIT BREAKERS 9

Type tests and routine tests – Short circuit testing – Synthetic testing of circuit breakers – Recent advancements in high voltage circuit breakers.

L:45 TOTAL:45PERIODS

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”, Elsevier India Pvt. Ltd, 2005.
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, 1982.
4. Ananthakrishnan S and Guruprasad K.P., “Transient Recovery Voltage and Circuit Breakers”, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1999.
5. Funio Nakanishi, “Switching Phenomena in High Voltage Circuit Breakers”, Marcel Dekker Inc., New York, 1991.

15HE23C DESIGN OF INSULATIONS FOR HIGH VOLTAGE EQUIPMENTS **L T P C**
3 2 0 4

COURSE OUTCOMES

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

CO 1: interpret the performance of insulating systems (K3)
CO 2: outline the basic concepts of insulating materials for high voltage application (K4)
CO 3: design the insulators, capacitors and bushings (K5)
CO 4: make use of the insulation schemes, design the power transformer (K5)
CO 5: evaluate the design parameters related to instrumental transformers (K5)

UNIT I INTRODUCTION 15

Basic arrangements of the insulation systems- Measures to avoid intensification of electric stress – Rigid and leak proof connections to insulating parts – Measures for air sealing oil insulated devices – temperature rise calculation of insulating systems - factors affecting the performance of Dielectric materials - Electric field distribution-utilization factor.

UNIT II INSULATING MATERIALS IN HIGH VOLTAGE TECHNOLOGY 15

Requirements of insulating materials – Properties and testing of insulating materials – Natural organic and inorganic materials – Synthetic organic insulating materials.

UNIT III DESIGN OF INSULATORS, BUSHINGS AND CAPACITORS 15

High Voltage capacitors - Basic configurations – Design of wound capacitors – Types of design, Bushings and lead outs – basic configuration – calculations of capacitive grading – Types of design.

UNIT IV DESIGN OF POWER TRANSFORMERS 15

Insulation schemes in transformer, design of transformer windings, surge phenomena in Transformer windings-effect of series and shunt capacitance and stress control techniques.

UNIT V DESIGN OF INSTRUMENT TRANSFORMERS 15

Instrument transformer- inductive voltage transformers – circuitry – error calculation – design-capacitive voltage transformers - circuitry – error calculation – design – current transformers - circuitry – error calculation – design.

L :45 T:30 TOTAL:75 PERIODS

REFERENCES

1. Dieter Kind and Hermann Karner, “High Voltage insulation technology”, translated from German by Y.Narayana Rao, Friedr. Vieweg & Sohn, Braunschweig, 1985.
2. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005
3. Pritindra Chowdhari, “Electromagnetic transients in Power System”, John Wiley and Sons Inc., 1996.
4. Alston, L.L, “High Voltage Technology”, Oxford University Press, London 1968.
5. Karsai, K.Kerenyi, D. and Kiss. L., “Large Power Transformers”, Elsevier, Armsterdam, 1987.
6. Feinberg, R., “Modern Power Transformer Practice”, the Macmillan Press Ltd., New York, 1979.

15HE24C EXTRA HIGH VOLTAGE POWER TRANSMISSION

L	T	P	C
3	2	0	4

COURSE OUTCOMES

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

CO 1: explain the role of EHVAC Transmission and Mechanical considerations (A3)
CO 2: calculate the line parameters for multi-conductor lines (K4)
CO 3: estimate the voltage gradients of conductors (K6)
CO 4: discuss the concepts of corona and radio interference (A2)
CO 5: illustrate the effect of electrostatic field on humans and vehicles (K4)

UNIT I INTRODUCTION 15

EHVAC Transmission – Line trends and preliminary aspects – Standard transmission voltages – power handling capacities and line losses – Mechanical aspects.

UNIT II CALCULATION OF LINE PARAMETERS 15

Calculation of resistance, inductance and capacitance for multiconductor lines – Calculation of sequence inductances and capacitances – Line parameters for different modes of propagation – Resistance and inductance of ground return.

UNIT III VOLTAGE GRADIENTS OF CONDUCTORS 15

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.

UNIT IV CORONA EFFECTS 15

Power losses and audible losses: I^2R 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.

UNIT V ELECTROSTATIC FIELD OF EHV LINES 15

Effect of EHV line on heavy vehicles – Calculation of electrostatic field of AC lines – Effect of high field on humans, animals, and plants – Electrostatic induction in un-energized circuit of a D/C line – Induced voltages in insulated ground wires.

L:45 T:30 TOTAL:75 PERIODS

REFERENCES

1. Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, New Age International Pvt. Ltd., Second Edition, 2011.
2. Power Engineer’s Handbook, TNEB Engineers Association, Revised and Enlarged Sixth Edition, October 2002.
3. Microtran Power System Analysis Corporation, Microtran Reference Manual, Vancouver Canada. (Website: www.microtran.com)

15HE25C HIGH VOLTAGE LABORATORY – II **L T P C**
0 0 4 2

COURSE OUTCOMES

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

CO 1: evaluate the breakdown strength of solid dielectrics (K5)
CO 2: measure the generated AC, DC and Impulse voltage (K5)
CO 3: determine the AC and DC breakdown voltage of gaseous dielectric (K5)
CO 4: examine the partial discharge and THD behavior of dielectric materials (K4)
CO 5: perform the power frequency and impulse voltage test on insulators and cable (S2)

LIST OF EXPERIMENTS

1. Measurement of dielectric strength of solid dielectric (Rubber gloves)
2. Measurement of capacitance and tan delta using high voltage Schering Bridge
3. Generation and measurement of AC, DC and Impulse voltage
4. Breakdown measurement of gaseous dielectric under AC Voltage
5. Breakdown measurement of gaseous dielectric under DC Voltage
6. Measurement of Partial discharge in dielectric using Partial Discharge Meter
7. Measurement of total harmonics distortion (THD) using harmonic analyzer
8. Earth resistance measurement
9. Power frequency test on Insulators
10. Power frequency test on Cables
11. Lightning Impulse voltage test on 11kV Pin type insulator
12. Lightning Impulse voltage test on 11kV Disc type insulator

P: 60 TOTAL: 60 PERIODS

15HE26C RESEARCH PAPER AND PATENT REVIEW – SEMINAR

L	T	P	C
0	0	4	2

The student will make at least two technical presentations on recent research publication and patent related to their specialization. The presentations will be assessed by a committee constituted by the head of the department. The students also expected to submit a report at the end of the semester.

P: 60 TOTAL: 60 PERIODS

15HE01E ELECTROMAGNETIC INTERFERENCE AND ELECTROMAGNETIC COMPATIBILITY **L T P C 3 0 0 3**

COURSE OUTCOMES

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

CO 1: describe the characteristics and design of electromagnetic compatibility (A1)
CO 2: discuss the methods of coupling and grounding (K6)
CO 3: summarize filtering, shielding and coating methods (K2)
CO 4: explain the digital logic noise and ground noise (A3)
CO 5: list the standard and laboratory techniques (K1)

UNIT I INTRODUCTION 9

Sources of EMI – Conducted and radiated interference – Characteristics – Designing for electromagnetic compatibility (EMC) – EMC regulation – Typical noise path – Use of network theory – Methods of eliminating interferences.

UNIT II METHOD OF GROUNDING 9

Cabling – capacitive coupling - inductive coupling - shielding to prevent magnetic radiation - shield transfer impedance - Grounding – safety grounds – signal grounds - single point and multipoint ground systems- hybrid grounds - functional ground layout – grounding of cable shields- ground loops - guard shields.

UNIT III BALANCING, FILTERING AND SHIELDING 9

Power supply decoupling – Decoupling filters – Amplifier filtering – High frequency filtering shielding – near and far fields – Shielding effectiveness – Absorption and reflection loss – Shielding with magnetic material – Conductive gaskets – Windows and coatings – Grounding of shields.

UNIT IV DIGITAL CIRCUIT NOISE AND LAYOUT 9

Frequency versus time domain – Analog versus digital circuits – Digital logic noise – Internal noise sources – Digital circuit ground noise – Power distribution – Noise voltage objectives – measuring noise voltages – Unused inputs – Logic families.

UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND LABORATORY TECHNIQUES 9

Static Generation – Human body model – Static discharges – ED protection in equipment design – ESD versus EMC - Industrial and Government standards – FCC requirements – CISPR recommendations –Laboratory techniques – Measurement methods for field strength – EMI.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Henry W.Ott, “Noise reduction techniques in electronic systems”, John Wiley & Sons, 2011.
2. Bernhard Keiser, “Principles of Electro-magnetic Compatibility”, Artech House, Inc. (685 canton street, Norwood, MA 020062 USA) 1987.
3. Bridges J.E., Milleta J. and Ricketts L.W., “EMP Radiation and Protective techniques”, John Wiley and sons, USA 1976.
4. IEEE National Symposium on “Electromagnetic Compatibility”, IEEE, 445, Hoes Lane, Piscataway, NJ 08854. USA.

15HE02E **PULSE POWER ENGINEERING** **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO1: identify the static and dynamic breakdown strength of dielectric materials. (K3)
CO2: estimate energy storage in Marx generators and pulse discharge capacitors. (K6)
CO3: distinguish the types and operation of various switches. (K4)
CO4: illustrate the pulse forming networks (K2)
CO5: appraise the pulse transmission and transformation theory. (K5)

UNIT I STATIC AND DYNAMIC BREAKDOWN STRENGTH OF DIELECTRIC MATERIALS **9**

Introduction – Gases-static breakdown – Pulsed breakdown – Spark formation – Liquids – Basic electrical process – Steamer breakdown – Practical considerations – Solids – General observation – Charge transport – Injection and Breakdown – Statistical Interpretation of breakdown Strength Measurements.

UNIT II ENERGY STORAGE **9**

Pulse Discharge Capacitors – Marx Generators – Classical Marx generators – LC Marx Generator – Basic Pulsed – Power Energy Transfer Stage – Inductive energy storage – Power and voltage multiplication – Rotors and homo polar Generators.

UNIT III SWITCHES **9**

Closing switches – Gas switches – Semi conductor closing switches – Magnetic switches – Summary –Opening switches – Fuses – Mechanical interrupters – Superconducting opening switches – Plasma opening switches – Plasma flow switches – Semiconductor opening switches.

UNIT IV PULSE FORMING NETWORKS **9**

Transmission lines – Terminations and junctions – Transmission lines with losses – The finite transmission line as a circuit element – Production of pulses with lossless transmission lines – RLC networks – Circuit simulation with LEITER.

UNIT V PULSE TRANSMISSION AND TRANSFORMATION **9**

Self magnetic insulation in vacuum lines – Vacuum break down in metallic surfaces – Qualitative description of self magnetic insulation – Quantitative description of self magnetic insulation – Pulse Transformers – High Voltage Power supplies – Capacitor-Charging Techniques – Cascade Circuits –Transformation Lines.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Hansjoachim Bluhm, “Pulsed Power Systems: Principles and Applications”, Springer; 2006.
2. Pai S.T., “Introduction to High Power Pulse Technology (Advanced Series in Electrical and Computer Engineering)”, Wspc Publisher, 1995.
3. Paul W. Smith, “Transient Electronics: Pulsed Circuit Technology”, Wspc, Wiley; First Edition 2002

15HE03E ADVANCED ELECTROMAGNETIC FIELDS L T P C
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the basic concepts in electrostatics. (K5)
CO 2: illustrate the concepts of electric fields and space charge free fields. (K2)
CO 3: distinguish the different techniques for analyzing the electric fields. (K4)
CO 4: analyze the electric fields with combination of different computation techniques. (K4)
CO 5: estimate the electric fields behavior in conductors and dielectrics. (K6)

UNIT I ELECTROSTATICS 9

Electrostatic Fields – Coulomb's Law – Electric Field Intensity (EFI) – EFI due to a line and a surface charge – Work done in moving a point charge in an electrostatic field – Electric Potential – Properties of potential function – Potential gradient – Gauss's law – Application of Gauss's Law – Maxwell's first law – Laplace's and Poisson's equations – Solution of Laplace's equation in one variable.

UNIT II ELECTRIC FIELDS-1 9

Introduction – Analytical calculation of space charge free fields – Simple geometries – Transmission conductors to ground – Fields in multi dielectric media – Experimental analogs for space charge free fields – Electrolytic tank – Semi conducting paper analog – Resistive mesh analog.

UNIT III ELECTRIC FIELDS-2 9

Numerical computation of space charge free fields – Successive imaging technique – The dipole method - charge-simulation technique – Finite-difference technique – Combined charge simulation and finite difference technique – Finite element technique – Combined charge simulation and finite element technique – Boundary element method – Integral equations technique – Montecarlo technique.

UNIT IV ELECTRIC FIELDS-3 9

Analytical calculations of fields with space charges – Numerical computation of fields with space charges finite element technique – Finite element technique combined with the method of characteristics – Charge simulation technique combined with the method of residues – Electric stress control and optimization.

UNIT V CONDUCTORS & DIELECTRICS 9

Behavior of conductors in an electric field – Conductors and insulators – Electric field inside a dielectric material – Polarization – Dielectric – Conductor and dielectric – Dielectric boundary conditions – Energy stored and energy density in a static electric field – Current density – Conduction and convection current densities – Ohm's law in point form – Equation of continuity.

L :45 TOTAL:45 PERIODS

REFERENCES

1. William H. Hayt andJohn. A. Buck, "Engineering Electromagnetics", Tata McGraw-Hill Companies, Seventh Edition, 2012.
2. Kraus J. D., "Electromagnetics", McGraw-Hill Inc., Fourth Edition, 1999.
3. Gangadhar, "Field Theory", Khanna Publishers, 2002.
4. Sadiku, "Elements of Electromagnetic field theory", Oxford Publication, 2010.
5. Paul C.R. and Nasar S.A., "Introduction to E-Magnetics", Tata McGraw-Hill Publications, 2005.

15HE04E POLLUTION PERFORMANCE OF POWER APPARATUS AND SYSTEMS

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO 1: explain the Mechanism of pollution flashover, Analytical determination. (K5)
CO 2: perform the artificial pollution testing methods. (S2)
CO 3: discuss the pollution performance of insulators. (K6)
CO 4: illustrate the pollution performance of surge diverters. (K2)
CO 5: demonstrate the pollution performance of indoor equipments.(A3)

UNIT I INTRODUCTION 9

Fundamental process of pollution flashover – Development and effect of contamination layer – Creepage distance – Pollution conductivity – Mechanism of pollution flashover – Analytical determination of flashover voltage.

UNIT II POLLUTION TESTING 9

Artificial pollution testing – Salt-fog method – Solid layer method – Monitoring of parameters – Measurement of layer conductivity – Field testing methods.

UNIT III POLLUTION PERFORMANCE OF INSULATORS 9

Ceramic and non-ceramic insulators – Design of shed profiles and their effect in insulators – Rib factor effect in AC and DC insulators – Various techniques to improve the performance of insulators – Modeling of insulators – Study of Flashover performance of various types of Insulators with non uniform pollution.

UNIT IV POLLUTION PERFORMANCE OF SURGE DIVERTERS 9

External insulation – Effect of pollution on the protective characteristics of gap and gapless arresters – Modeling of surge diverters under polluted conditions.

UNIT V POLLUTION PERFORMANCE OF INDOOR EQUIPMENT 9

Condensation and Contamination of indoor switch gear – Performance of organic insulator under polluted conditions – Accelerated testing techniques.

L:45 TOTAL:45 PERIODS

REFERENCES

1. Kind and Karner, “High Voltage Insulation”, Translated from German by Y.Narayana Rao, Frider. Vieweg, & Sohn, Braunschweig, Weishaden, 1985.
2. Kuffel E., Zaengl W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005.
3. Klaus Ragaller, “Surges in High Voltage Networks”, Plenum Press, New York, 1980.
4. Zhijin Zhang, Xiaohuan Liu, Xingliang Jiang, Jianlin Hu, and David Wenzhong Gao, “Study on AC Flashover Performance for Different Types of Porcelain and Glass Insulators With Non-Uniform Pollution”, IEEE Transactions on Power Delivery, Vol. 28, No. 3, July 2013, pp. 1691 – 1698.
5. Dieter Kind and Kurt Feser, “High Voltage Test Techniques”,SBA Electrical Engineering Series, New Delhi, Second Edition,1999.

15HE05E HIGH VOLTAGE DIRECT CURRENT TRANSMISSION **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: describe the DC power transmission technology (A1)
CO 2: analyze HVDC converters (K4)
CO 3: describe the various types, control and protection of MTDC systems (A1)
CO 4: analyze harmonics and filters (K4)
CO 5: discuss the simulation tools and modeling of HVDC system (K6)

UNIT I 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 – DC breakers – Cables – VSC based HVDC.

UNIT II ANALYSIS OF HVDC CONVERTERS AND HVDC SYSTEM CONTROL 9

Pulse number – Choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – Detailed analysis of converters - General principles of DC link control – Converter control – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering.

UNIT III MULTITERMINAL DC SYSTEMS 9

Introduction – Potential applications of MTDC systems – Types of MTDC systems – Control and protection of MTDC systems – Study of MTDC systems.

UNIT IV POWER FLOW ANALYSIS IN AC/DC SYSTEMS 9

Per unit system for DC Quantities – Modeling of DC links – Solution of DC load flow – Solution of AC-DC power flow – Case studies.

UNIT V SIMULATION OF HVDC SYSTEMS 9

Introduction – System simulation: Philosophy and tools – HVDC system simulation – Modeling of HVDC systems for digital dynamic simulation – Dynamic interaction between DC and AC systems.

L :45 TOTAL:45 PERIODS

REFERENCES

1. Padiyar K.R., “HVDC Power Transmission Systems”, New Age International (P)Ltd., New Delhi, 2002.
2. Arrillaga J., “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 2007.
3. Kundur P., “Power System Stability and Control”, Tata McGraw-Hill, 1993.
4. Erich Uhlmann, “Power Transmission by Direct Current”, BS Publications, 2004.
5. Sood V.K., “HVDC and FACTS controllers – Applications of Static Converters in Power System”, Kluwer Academic Publishers, April 2004

15HE06E COLLISION PHENOMENON **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the concepts of collision phenomenon. (A3)
CO 2: discuss the behavior of charged particles in gaseous medium under different electric fields conditions. (K6)
CO 3: illustrate the concept of self sustaining discharge breakdown mechanisms. (K2)
CO 4: summarize the concepts of partial discharge and breakdown mechanism under alternating fields. (K2)
CO 5: explain the concepts of breakdown, glow and plasma. (K5)

UNIT I INTRODUCTION 9

Ionization, Deionization and Electron Emission – Ionization and plasma conductivity – Production of charged particles – Ionization by cosmic rays – Thermal ionization – The free path – Excited states – Metastable states – Diffusion – Recombination – Negative ions – Photoelectric emission – Thermionic emission – Field emission.

UNIT II BEHAVIOUR OF CHARGED PARTICLES IN A GAS IN ELECTRIC FIELDS OF LOW E/p AND HIGH E/p 9

Definition and significance of mobility – Forces between ions and molecules – Diffusion under low fields – Electron drift velocity – High E/p – Coefficient of ionization by electron collision – Evaluation of $\propto$ – Electron avalanche – Effect of the cathode – Ionization coefficient in alternating fields.

UNIT III SELF-SUSTAINING DISCHARGE BREAKDOWN MECHANISMS 9

Ionization by positive-ion collision – Cathode processes – Space-charge field of an avalanche – Critical avalanche size – Townsend mechanism and its limitations – Streamer formation – The transition between the breakdown mechanisms – The effect of electron attachment.

UNIT IV PARTIAL BREAKDOWN AND BREAKDOWN UNDER ALTERNATING FIELDS 9

Electron current – Positive ion current – Total current – Characteristic time – Effect of space charge – Anode coronas – Cathode coronas.

UNIT V BREAKDOWN GLOW AND PLASMA 9

Breakdown: Mobility controlled breakdown – Microwave of diffusion controlled breakdown – Non-uniform alternating field breakdown – Laser breakdown.Glow and Plasma: General description – The cathode zone – Negative glow and Faraday dark space – Positive column – Anode region – Other effects – Definition of plasma – Debye length – Scope of known plasmas – Plasma oscillations – High-temperature plasmas – Plasma diagnostics.

L :45 TOTAL:45 PERIODS

REFERENCES

1. Essam Nasser, “Fundamentals of Gaseous Ionization and Plasma Electronics”, John Willey & Sons, 1971.
2. Alexander Fridman and Lawrence A Kennedy, “Plasma Physics and Engineering”, Taylor & Francis, 2004.
3. Kwan Chi Kao, “Dielectric Phenomena in Solids [Electronic Resource]”, Academic Press 2004

15HE07E ADVANCED TOPICS IN HIGH VOLTAGE ENGINEERING

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO 1: discuss the measurement and diagnostic technologies (K6)
CO 2: list the various application of high voltage engineering in industry. (K1)
CO 3: explain about the safety and electrostatic hazards, Lightning protection. (K5)
CO 4: analyze the electrical breakdown, pulse generators and treatment chamber design (K4)
CO 5: apply PEF technology in food preservation (K3)

UNIT I MEASUREMENT AND DIAGNOSTIC TECHNOLOGIES 9

Introduction – Digital Impulse Recorders – Digital Techniques in HV tests – Testing automation – Electric field measurement – Electro-optic Sensors- Magneto-optic Sensors – Measurement of very fast transients in GIS – Space charge measurement techniques – Electro-optical imaging techniques.

UNIT II APPLICATION OF HIGH VOLTAGE ENGINEERING IN INDUSTRY 9

Introduction – Electrostatic applications – Electrostatic precipitation, separation, painting coating, spraying, imaging, printing – Transport of materials – Sandpaper Manufacture – Smoke particle detector – Electrostatic spinning, pumping, propulsion – Ozone generation – Biomedical applications.

UNIT III SAFETY AND ELECTROSTATIC HAZARDS 9

Introduction – Nature of static electricity – Triboelectric series – Basic laws of Electrostatic electricity – Materials and static electricity – Electrostatic Discharges (ESD) – Static electricity problems – Hazards of Electrostatic electricity in industry – Hazards from electrical equipment and installations – Static eliminators and charge neutralizers – Lightning protection.

UNIT IV PULSED ELECTRIC FIELDS 9

Introduction – Definitions, descriptions and applications – Mechanisms of microbial inactivation's – Electrical breakdown – Electroporation – Inactivation models – Critical factors analysis of process, product and microbial factors – Pulse generators and treatment chamber design – Research needs.

UNIT V APPLICATION OF PEF TECHNOLOGY IN FOOD PRESERVATION 9

Processing of juices, milk, egg, meat and fish products – Processing of water and waste – Industrial feasibility, cost and efficiency analysis.

L:45 TOTAL: 45 PERIODS

REFERENCES

1. Malik N.H., Ai-Arainy A.A., Qureshi M.I., "Electrical Insulation in Power Systems", Marcel Dekker, Inc., 1998.
2. Mazen Abdel-Salam, Hussien Anis, Ahdab EI-Morshedy, "High Voltage Engineering", Theory and Practice, Marcel Dekker Inc., 2nd Edition, 2000,
3. John D Kraus, Daniel A Fleisch, "Electromagnetics with Applications" Tata McGraw- Hill International Editions, 1992.
4. Shoait Khan, "Industrial Power System", CRC Press, Taylor & Francis group, 2008.
5. Barbosa-Canovas G.V., "Pulsed electric fields in food processing: Fundamental aspects and applications" CRC Publisher Edition, March 1st,2001.
6. Lelieveld H.L.M., Notermans S., et al, "Food preservation by pulsed electric fields: From research to application", Woodhead Publishing Ltd, October 2007.

15HE08E HIGH VOLTAGE FIELDS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO1: analyze the 2D and 3D dielectric systems using finite difference method (K4)
CO 2: apply charge simulation method to analyze single and multi dielectric media (K3)
CO 3: estimate the field parameters using finite element method (K6)
CO 4: formulate 2D and 3D dielectric systems using boundary element method (A4)
CO 5: list the analytical methods of electric field calculation (K1)

UNIT I FINITE DIFFERENCE METHOD 9

FDM formulations for homogeneous medium in 3-D system with unequal nodal distances – FDM formulations for multi-dielectric media in 2-D system with unequal nodal distances – FDM formulations for multi-dielectric media in axi-symmetric system with equal nodal distances.

UNIT II CHARGE SIMULATION METHOD 9

Charge Simulation method in single-dielectric and multi-dielectric media – Types of fictitious charges: Point charge – Infinite and finite length line charge – Ring charge – Accuracy Criteria – Factors affecting simulation accuracy – Solution of system of equations – Least Square Error CSM – Optimized CSM – Region oriented CSM – CSM with complex fictitious charges – Application of CSM for lossy dielectric considering volume and surface resistivities – Application of CSM for field calculation under transient voltages for lossy dielectric.

UNIT III FINITE ELEMENT METHOD 9

Minimum field energy and basic potential equation at nodes for triangular elements considering homogeneous medium and also multi-dielectric media for two-dimensional and axi-symmetric field – Element interpolation – Simplex coordinates – Simplex-Cartesian relation – Interpolation on 1 Simplexes – Interpolation functions on n-Simplexes – Interpolation for curvilinear elements – Local coordinates – Integration by Gauss Quadrature Method – Hybrid method comprising CSM and FEM – Comparison between CSM and FEM.

UNIT IV BOUNDARY ELEMENT METHOD 9

Basic formulations for 2-D and 3-D systems based on Green's function kernel – Fundamental solution and weighting function for solution – Evaluation of integrals for constant and linear elements – Treatment of corners – Multi-boundary problems – Multi-dielectric system. Surface Charge Simulation Method – Basic formulations for 2-D and axi-symmetric systems considering ideal homogeneous medium – Straight-line and elliptic arc elements – Formulations for lossy dielectric including volume and surface resistivity.

UNIT V ANALYTICAL METHODS OF ELECTRIC FIELD CALCULATION 9

Solution of field perturbations due to a long conducting/dielectric cylinder in uniform field – Solution of field perturbations due to a conducting/dielectric sphere in uniform field. Mechanical forces in HV systems: Mechanical pressure on electrode boundary – Mechanical pressure within an insulator – Film pressure on insulator boundary –Total pressure at the insulator – Insulator boundary.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Tadasu Takuma, Boonchai Techaumnat, "Electric Fields in Composite Dielectrics and their Applications", Springer, 2010
2. Hayt," Problems & Solutions In Electromagnetics", Tata McGraw Hill, 2011
3. Pei-bai Zhou, "Numerical analysis of electromagnetic fields", Spinger, 1993.
4. William H. Hayt andJohn. A. Buck, "Engineering Electromagnetics", Tata McGraw-Hill Companies, Seventh Edition, 2012.
5. Kraus J. D., "Electromagnetics", McGraw-Hill Inc., Fourth Edition, 1999.

15HE09E FLEXIBLE AC TRANSMISSION SYSTEMS L T P C
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the fundamental idea about FACTS controllers. (K5)
CO 2: design of SVC voltage regulator using TCR-TSC logic. (K6)
CO 3: describe Transient stability model of TCSC. (A1)
CO 4: explain about basic principle of operation of STATCOM. (A3)
CO 5: explain controller interactions & its types. (K2)

UNIT I INTRODUCTION 9

Reactive power control in electrical power transmission lines – Uncompensated transmission line – series compensation – Basic concepts of Static Var Compensator (SVC) – Thyristor Controlled Series capacitor (TCSC) – Unified power flow controller (UPFC).

UNIT II STATIC VAR COMPENSATOR (SVC) AND APPLICATIONS 9

Voltage control by SVC – Advantages of slope in dynamic characteristics – Influence of SVC on system voltage – Design of SVC voltage regulator –Modeling of SVC for power flow and transient stability – Applications: Enhancement of transient stability – Steady state power transfer – Enhancement of power system damping – Prevention of voltage instability.

UNIT III THYRISTOR CONTROLLED SERIES CAPACITOR AND APPLICATIONS 9

Operation of the Thyristor Controlled Series Capacitor (TCSC) – Different modes of operation – Modeling of TCSC – Variable reactance model – Modeling for Power Flow and stability studies – Applications: Improvement of the system stability limit – Enhancement of system damping-SSR Mitigation.

UNIT IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9

Static Synchronous Compensator (STATCOM) – Principle of operation – V-I Characteristics – Applications: Steady state power transfer – Enhancement of transient stability – Prevention of voltage instability – SSSC – Operation of SSSC and the control of power flow – Modeling of SSSC in load flow and transient stability studies – Applications: SSR Mitigation – UPFC and IPFC.

UNIT V CO-ORDINATION OF FACTS CONTROLLERS 9

Controller interactions – SVC – SVC interaction – Coordination of multiple controllers using linear control techniques – Control coordination using genetic algorithms.

L:45 TOTAL:45 PERIODS

REFERENCES

1. Mohan Mathur R. and Rajiv K. Varma, “Thyristor – Based Facts Controllers for Electrical Transmission Systems”, IEEE press and John Wiley & Sons, Inc, 2002.
2. Narain G. Hingorani, “Understanding FACTS -Concepts and Technology of Flexible AC Transmission Systems”, Standard Publishers Distributors, Delhi.
3. Padiyar K.R.,” FACTS Controllers in Power Transmission and Distribution”, New Age International (P) Limited, Publishers, New Delhi, 2008.
4. John A.T., “Flexible A.C. Transmission Systems”, Institution of Electrical and Electronic Engineers (IEEE), 1999.
5. Sood V.K., “HVDC and FACTS controllers – Applications of Static Converters in Power System”, Kluwer Academic Publishers, April 2004.

15HE10E POWER QUALITY **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the production of voltages sags, over voltages and harmonics and methods of control. (K2)
CO 2: list the various methods of power quality monitoring (K1)
CO 3: discuss the various types of measurements and analysis methods. (K6)
CO 4: outline the concepts of Mitigation methods. (K2)
CO 5: Illustrate the overview of power quality improvement (K2)

UNIT I 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.

UNIT II 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.

UNIT III 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.

UNIT IV 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 – Detroit 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.

UNIT V 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 TOTAL:45 PERIODS

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, 2nd Edition, 1994.
3. Duggan R.C., "Electrical Power Systems Quality", McGraw-Hill, 2012.
4. Arrillga A.J., "Power system harmonics", John Wiley & Sons Ltd., 2nd Edition, 2003.
   Derek A Paice, "Power electronic converter harmonics", IEEE Press, 1996.

15HE11E RESTRUCTURED POWER SYSTEMS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: list the operators involved in Restructured market and methods used for pricing and congestion process. (K1)
CO 2: explain the functions and operations of U.S. Re-structured markets.(K2)
CO 3: evaluate the structure and functions of OASIS and ATC calculation. (K5)
CO 4: discuss the importance, factors and derivative instruments of electric energy trading. (K6)
CO 5: identify the factors and challenges of electric price volatility and forecasting methods. (A1)

UNIT I OVERVIEW OF KEY ISSUES IN ELECTRIC UTILITIES ESTRUCTURING 9

Restructuring Models: Pool Co Model, Bilateral Contracts Model, Hybrid Model – Independent System Operator (ISO): The Role of ISO – Power Exchange (PX): Market Clearing Price (MCP) – Market operations: Day-Ahead and Hour-Ahead Markets – Elastic and Inelastic Markets – Market Power – Stranded costs – Transmission Pricing: Contract Path Method – The MW-Mile Method – Congestion Pricing: Congestion Pricing Methods – Transmission Rights – Management of Inter-Zonal/Intra Zonal Congestion: Solution procedure – Formulation of Inter-Zonal Congestion Sub problem – Formulation of Intra-Zonal Congestion Sub problem.

UNIT II ELECTRIC UTILITY MARKETS IN THE UNITED STATES 9

California Markets: ISO, Generation, Power Exchange, Scheduling Co-ordinator, UDCs, Retailers and Customers, Day-Ahead and Hour-Ahead Markets – Block forwards Market – Transmission Congestion Contracts(TCCs) – New York Market: Market operations – PJM interconnection – Ercot ISO – New England ISO – Midwest ISO: MISO's Functions – Transmission Management – Transmission System Security – Congestion Management – Ancillary Services Coordination – Maintenance Schedule Coordination – Summary of functions of U.S. ISOs.

UNIT III OASIS: OPEN ACCESS SAME TIME INFORMATION SYSTEM 9

FERC order 889 – Structure of OASIS: Functionality and Architecture of OASIS – Implementation of OASIS Phases: Phase 1 – Phase 1-A – Phase 2 – Posting of information: Types of information available on OASIS – Information requirement of OASIS – Users of OASIS – Transfer Capability on OASIS: Definitions – Transfer Capability Issues – ATC Calculation – TTC Calculation – TRM Calculation – CBM Calculation – Transmission Services – Methodologies to Calculate ATC – Experiences with OASIS in some Restructuring Models: PJM OASIS – ERCOT OASIS.

UNIT IV ELECTRIC ENERGY TRADING 9

Essence of Electric Energy Trading – Energy Trading Framework: The Qualifying factors – Derivative Instruments of Energy Trading: Forward Contracts – Futures Contracts – Options – Swaps – Applications of Derivatives in Electric Energy Trading – Portfolio Management: Effect of Positions on Risk Management – Energy Trading Hubs – Brokers in Electricity Trading – Green Power Trading.

UNIT V ELECTRICITY PRICING - VOLATILITY, RISK AND FORECASTING 9

Electricity Price Volatility: Factors in Volatility – Measuring Volatility – Electricity Price Indexes: Case Study for Volatility of Prices in California – Basis Risk – Challenges to Electricity Pricing: Pricing Models – Reliable Forward Curves – Construction of Forward Price Curves: Time frame for Price Curves – Types of Forward Price Curves – Short-term Price Forecasting: Factors Impacting Electricity Price – Forecasting Methods – Analyzing Forecasting Errors – Practical Data Study.

L :45 TOTAL:45 PERIODS

REFERENCES

1. Jain M.K. and Rao N.D., G.J.Berg, "Improved Area Interchange Control Method for use with any Numerical Technique", I.E.E.E. P.E.S Winter Power Meeting 1974.
2. Britton J.P., "Improved Area Interchange Control for Newton's method Load Flows", Paper 69 TP 124-PWR presented at IEEE Winter Power Meeting, NewYork, Jan 26-31, 1969.
3. Tinney W.F. and Meyer W.S., "Solution of Large Sparse System by Ordered Triangular Factorization" IEEE Trans. on Automatic Control, Vol: AC-18, pp: 333-346, Aug 1973.
4. Zollenkopf K., "Bi-Factorization: Basic Computational Algorithm and Programming Techniques; pp: 75-96, 1970.
5. Book on "Large Sparse Set of Linear Systems" Editor: Rerd J.K., Academic Press, 1971.

15HE12E POWER SYSTEM PLANNING AND RELIABILITY **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: outline the objectives and importance of load forecasting and the methods involved in it. (K2)
CO 2: evaluate the LOLP and reliability of ISO. (K5)
CO 3: perform contingency analysis and load flow reliability analysis.(S2)
CO 4: explain the concept, procedure and problems faced in Expansion planning. (A3)
CO 5: develop the planning, protection and coordination of protective devices in distribution systems. (K6)

UNIT I LOAD FORECASTING 9

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

UNIT II GENERATION SYSTEM RELIABILITY ANALYSIS 9

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

UNIT III TRANSMISSION SYSTEM RELIABILITY ANALYSIS 9

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

UNIT IV EXPANSION PLANNING 9

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

UNIT V DISTRIBUTION SYSTEM PLANNING OVERVIEW 9

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

L :45 TOTAL:45 PERIODS

REFERENCES

1. Sullivan R.L., “Power System Planning”, Tata McGraw-Hill, US, 1977.
2. Roy Billinton and Allan Ronald, “Power System Reliability”, Gordon and Breach, Science Publishers, 1970.
3. Proceeding of work shop on energy systems planning & manufacturing CI.
4. Turan Gonen, “Electric power distribution system engineering”, Tata McGraw-Hill, 1986.

15HE13E POWER SYSTEM ANALYSIS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: perform the various solution techniques for large scale power systems. .(S2)
CO 2: discuss the various load flow analysis techniques and assessment of ATC. (K6)
CO 3: illustrate the importance of optimal power flow and methods involved in calculating OPF. (K2)
CO 4: compute the fault analysis calculation using bus impedance matrix. (K5)
CO 5: analyze the numerical integration methods and factors influencing numerical and transient stability. (K4)

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 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.

UNIT III OPTIMAL POWER FLOW 9

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

UNIT IV SHORT CIRCUIT ANALYSIS 9

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.

UNIT V TRANSIENT STABILITY ANALYSIS 9

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

L: 45 TOTAL:45 PERIODS

REFERENCES

1. Stagg G.W. and El. Abiad A.H., "Computer Methods in Power System Analysis", Tata McGraw-Hill, 1968.
2. Kundur P., "Power System Stability and Control", Tata McGraw-Hill, 1994.

3. Wood A.J. and Wollenberg B.F., “Power Generation Operation and Control”, John Wiley and sons, New York, 1996.
4. Tinney W.F. and Meyer W.S., “Solution of Large Sparse System by Ordered Triangular Factorization” IEEE Trans. on Automatic Control, Vol.18, pp. 333-346, Aug 1973.
5. Zollenkopf K., “Bi-Factorization: Basic Computational Algorithm and Programming Techniques” pp. 75-96.
6. Book on “Large Sparse Set of Linear Systems” Editor: J.K.Rerd,Academic Press, 1971.

15HE14E POWER SYSTEM OPERATION AND CONTROL **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the basic concept of load prediction and various approaches. (K2)
CO 2: develop the various method to get the solution for constraints. (K6)
CO 3: formulate the generation scheduling and the economic dispatch. (K6)
CO 4: describe the various control strategies of power systems. (A1)
CO 5: Evaluate the state estimation using different algorithms. (K5)

UNIT I 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.

UNIT II 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 λ.

UNIT III GENERATION SCHEDULING 9

The Economic dispatch problem – Thermal system dispatching with network losses considered – The Lambda-iteration method – Gradient method of economic dispatch – Economic dispatch with Piecewise Linear cost functions – Transmission system effects – A two generator system – Coordination equations – Incremental losses and penalty factors – Hydro Thermal Scheduling using DP.

UNIT IV CONTROL OF POWER SYSTEMS 9

Review of AGC and reactive power control – 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.

UNIT V 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.

L :45, TOTAL:45 PERIODS

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 Wollenberg, “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,1984.

15HE15E REACTIVE POWER COMPENSATION AND MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO 1: discuss the basic concepts of load compensation. (K6)
CO 2: develop the reactive power compensation in transmission line and it's characteristic. (K6)
CO 3: illustrate the basic concepts of power quality and its issues. (K2)
CO 4: summarize the concepts of load shaping and tariffs. (K2)
CO 5: explain the reactive power management and its consideration**.** (K5)

UNIT I LOAD COMPENSATION 9

Objectives and specifications – Reactive power characteristics – Inductive and capacitive approximate biasing – Load compensator as a voltage regulator – Phase balancing and power factor correction of unsymmetrical loads – Examples.

UNIT II REACTIVE POWER COMPENSATION IN TRANSMISSION SYSTEM 9

Steady state reactive power compensation in transmission system: Uncompensated line – Types of compensation – Passive shunt and series and dynamic shunt compensation – Examples. Transient state reactive power compensation in transmission systems: Characteristic time periods – Passive shunt compensation – Static compensations – Series capacitor compensation – Compensation using synchronous condensers – Examples.

UNIT III REACTIVE POWER COORDINATION 9

Objective – Mathematical modeling – Operation planning – Transmission benefits – Basic concepts of quality of power supply – Disturbances – Steady – State variations – Effects of under voltages – Frequency – Harmonics – Radio frequency and electromagnetic interferences.

UNIT IV DEMAND SIDE MANAGEMENT 9

Load patterns – Basic methods load shaping – Power tariffs – KVAR based tariffs – Penalties for voltage flickers and Harmonic voltage levels.

UNIT V REACTIVE POWER MANAGEMENT 9

Distribution side Reactive power Management: System losses – Loss reduction methods – Examples – Reactive power planning – Objectives – Economics Planning capacitor placement – Retrofitting of capacitor banks. User side reactive power management: KVAR requirements for domestic appliances – Purpose of using capacitors – Selection of capacitors – Deciding factors – Types of available capacitor, characteristics and Limitations.

L :45 TOTAL:45 PERIODS

REFERENCES

1. Miller T.J.E., "Reactive power control in Electric power systems", John Wiley and sons, 1982.
2. Tagare D.M., "Reactive power Management", Tata McGraw-Hill, 2004

15HE16E POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

- CO 1: explain the importance of renewable energy and different renewable energy resources.(A3)
- CO 2: analyze of wind electrical generators. (K4)
- CO 3: design different power converters namely AC to DC, DC to DC and AC to AC converters for renewable energy systems. (S5)
- CO 4: analyze the grid integrated wind and PV systems.(K4)
- CO 5: develop maximum power point tracking algorithms. (K6)

UNIT I 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.

UNIT II ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION **9**

Review of reference theory fundamentals – Principle of operation and analysis: IG, PMSG, SCIG and DFIG.

UNIT III 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.

UNIT IV 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.

UNIT V 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).

L:45, TOTAL: 45 PERIODS

REFERENCES

1. Rashid M.H., “Power Electronics Hand book”, Academic press, 2011.
2. Rai G.D, “Non-conventional energy sources”, Khanna publishes, 2009.
3. Rai G.D,” Solar energy utilization”, Khanna publishes, 1993.
4. Gray L. Johnson, “Wind energy system”, prentice hall linc, 1995.
5. Khan B.H., “Non-conventional Energy sources”, Tata McGraw-Hill Publishing Company, New Delhi, 2006

15HE17E MODERN RECTIFIERS AND RESONANT CONVERTERS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain about the causes for arising the harmonics and basic filter techniques. (K5)
CO 2: discuss about the pulse width modulated rectifier and its control techniques. (K6)
CO 3: analyze the performance of resonant converter of its various types. (K4)
CO 4: develop the state space model and dynamic analysis of switching converter. (K6)
CO 5: design the various control schemes for resonant converter**.** (S5)

UNIT I POWER SYSTEM HARMONICS & LINE COMMUTATED RECTIFIERS 9

Average power – RMS value of waveform – Power factor – AC line current harmonic standards IEC1000 – IEEE 519 – The Single phase full wave rectifier – Continuous Conduction Mode – Discontinuous Conduction Mode – Behaviour – Minimizing THD – Three phase rectifiers – Continuous Conduction Mode – Discontinuous Conduction Mode – Harmonic trap filters.

UNIT II PULSE WIDTH MODULATED RECTIFIERS 9

Properties of Ideal rectifiers – Realization of non ideal rectifier – Control of current waveform – Average current control – Current programmed Control – Hysteresis control – Nonlinear carrier control – Single phase converter system incorporating ideal rectifiers – Modeling losses and efficiency in CCM high quality rectifiers-Boost rectifier Example – Expression for controller duty cycle – Expression for DC load current – Solution for converter Efficiency.

UNIT III RESONANT CONVERTERS 9

Review on Parallel and Series Resonant Switches – Soft Switching – Zero Current Switching – Zero Voltage Switching – Classification of Quasi resonant switches – Zero Current Switching of Quasi Resonant Buck converter – Zero Current Switching of Quasi Resonant Boost converter – Zero Voltage Switching of Quasi Resonant Buck converter – Zero Voltage Switching of Quasi Resonant Boost converter: Steady State analysis.

UNIT IV DYNAMIC ANLYSIS OF SWITCHING CONVERTERS 9

Review of linear system analysis – State Space Averaging – Basic State Space Average Model – State Space Averaged model for an ideal Buck Converter – Ideal Boost Converter – Ideal Buck Boost Converter – For an ideal Cuk Converter.

UNIT V CONTROL OF RESONANT CONVERTERS 9

Pulse Width Modulation – Voltage Mode PWM Scheme-Current Mode PWM Scheme – Design of Controllers: PI Controller – Variable Structure Controller – Optimal Controller for the source current shaping of PWM rectifiers.

L:45 TOTAL:45 PERIODS

REFERENCES

1. Robert W. Erickson and Dragon Maksimovic, “Fundamentals of Power Electronics”, Second Edition, Springer science and Business media, 2001.
2. William Shepherd and Li zhang, “Power Converters Circuits”, Marceld Ekkerin,C, 2005.
3. Simon Ang and Alejandro Oliva, “Power Switching Converters”, Taylor & Francis Group, 2010.

15HE18E ANALYSIS OF POWER CONVERTERS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the types and its principle operation of single phase AC-DC converter.(K5)
CO 2: discuss the various three phase AC-DC converter and its operation. (K6)
CO 3: illustrate about the types of DC-DC converter and fundamentals of Resonant converter (K2)
CO 4: distinguish the various inverter and its analysis with different loads. (K4)
CO 5: summarize the voltage controller, cyclo converter and matrix converter. (K2)

UNIT I SINGLE PHASE AC-DC CONVERTERS 9

Uncontrolled – Half controlled and fully controlled with RL, RLE loads and freewheeling diode – Continuous and discontinuous modes of operation – Inverter operation – Dual converter – Sequence control of converters – Performance parameters: Harmonics – Ripple – Distortion – Power factor – Effect of source impedance and overlap.

UNIT II THREE PHASE AC-DC CONVERTERS 9

Uncontrolled – Half controlled and fully controlled with RL, RLE loads and freewheeling diodes – Inverter operation and its limit – Dual converter – Performance parameter effect of source impedance and overlap.

UNIT III DC – DC CONVERTERS 9

Principles of step-down and step-up converters – Analysis of buck, boost – buck-boost and Cuk converters – Time ratio and current limit control – Full bridge converter – Resonant and Quasi-resonant converters.

UNIT IV DC – AC CONVERTERS 9

Voltage source inverters – Principle of operation of half and full bridge inverters – 180 degree and 120 degree conduction mode inverters – Voltage control of three phase inverters using various PWM techniques – Harmonics and various harmonic elimination techniques – Analysis with RL, RLE loads – Multi level inverters.

UNIT V AC – AC CONVERTERS 9

Principle of operation of AC Voltage Controllers – Cyclo converters – Analysis with RL, RLE loads – Introduction to Matrix converters.

L:45 TOTAL:45 PERIODS

REFERENCES

1. Ned Mohan, Undeland and Robbin, “Power Electronics: Converters, Application and Design”, A John Wiley and Sons Inc., Newyork, 2012.
2. Rashid M.H., “Power Electronics Circuits, Devices and Applications”, Prentice Hall of India, New Delhi, 2011.
3. Sen P.C, ”Modern Power Electronics”, Wheeler publishing Co, New Delhi, First Edition, 2005.
4. Bimbhra P.S., “Power Electronics”, Eleventh Edition, Khanna Publishers, 2003.
5. Bin Wu, “High Power Converters and AC Drives”, IEEE Press, A John Wiley and Sons Inc., 2006.

15HE19E POWER ELECTRONICS IN POWER SYSTEMS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: outline the fundamental concept of power electronic devices. (K2)
CO 2: explain the single phase and three phase power converter and its operation. (A3)
CO 3: discuss the single phase and three phase inverter with its control strategies. (K6)
CO 4: illustrate the reactive power compensation and the FACTS devices. (K2)
CO 5: appraise the power quality and various power quality problems.(K5)

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 Output 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 - Harmonics from commercial and industrial Loads –Devices for Controlling Harmonics – Passive and Active Filters – Harmonic Filter Design.

L :45 TOTAL: 45 PERIODS

REFERENCES

1. Ned Mohan, Undeland and Robbin, "Power Electronics: Converters, Application and Design", A John Wiley and Sons Inc., Newyork, 2012.
2. Rashid M.H., "Power Electronics Circuits, Devices and Applications", Prentice Hall of India, 2011.
3. Bose B.K., "Power Electronics and A.C. Drives", Prentice Hall, 2010.
4. Roger C Dugan, Mark F Mc Granaghan, Surya Santaso and Wayne Beaty H., "Electrical Power Systems Quality", Second Edition, Tata McGraw-Hill, 2003.
5. Miller T.J.E., "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 2002.

15HE20E CONTROL OF ELECTRIC DRIVES

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COURSE OUTCOMES

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

- CO 1: explain the concept of converter fed DC drives. (K5)
- CO 2: discuss the various modes of operation of chopper fed DC drives. (K6)
- CO 3: analyze the various inverters fed DC drives and its sampling techniques. (K4)
- CO 4: develop the mathematical model of the frequency controlled drive also to study the steady state and dynamic behavior. (K6)
- CO 5: perform the various measurement and control techniques**.** (S2)

UNIT I CONVERTER FED DC DRIVES 9

Microcontroller hardware circuit – Flow charts waveforms – Performance characteristics of dc drives fed through single phase converters – 3-phase converters – Dual converters – 1-phase fully controlled converter and 3-phase fully controlled converter fed dc drive.

UNIT II CHOPPER FED DC DRIVES 9

Microcontroller hardware circuits and waveforms of various modes of operation of chopper fed DC drives.

UNIT III INVERTER FED INDUCTION MOTOR DRIVE 9

Microcomputer controlled VSI fed induction motor drive – Detailed power circuit – Generation of firing pulses and firing circuit – Flow charts and waveforms for 1-phase, 3-phase Non-PWM and 3-phase PWM VSI fed induction motor drives – Sampling techniques for PWM inverter.

UNIT IV MATHEMATICAL MODELING OF FREQUENCY CONTROLLED DRIVE 9

Development of mathematical model for various components of frequency controlled induction drive – Mathematical model of the system for steady state and dynamic behavior – Study of stability based on the dynamic model of the system.

UNIT V CLOSED LOOP CONTROL OF MICROCOMPUTER BASED DRIVES 9

Voltage, Current, Torque and Speed measurements using digital measurement techniques – Types of controllers – Position and velocity measurement algorithm – Closed loop control of microcomputer based drives.

L :45 TOTAL:45 PERIODS

REFERENCES

1. Bose B.K., "Power Electronics and Motor Drives - Advances and Trends", IEEE Press, 2006.
2. Buxbaum, Schierau A., and Staughen K., "A design of control systems for DC drives", Springer- Verlag, Berlin, 1990.
3. Vedam Subrahmanyam, "Thyristor control of Electric drives", Tata McGraw-Hill, 1988.
4. Krishnan R., "Electric Motor Drives, Modeling, Analysis and Control", Prentice Hall of India, 2002.
5. Bin Wu, "High Power Converters and AC Drives", IEEE Press, A John Wiley and Sons, Inc., 2006.
6. Dubey G.K., "Power semiconductor controlled drives", Prentice-HALL,1989.
7. Leonard W., "Control of Electric Drives", Springer Verlag, NY, 1985.
8. Bose B.K., "Microcomputer control of power electronics and drives", IEEE Press, 1987.
9. Bose B.K., "Adjustable Speed A.C. drives", IEEE Press, 1993

15HE21E COMPUTER AIDED DESIGN OF POWER ELECTRONICS CIRCUITS L T P C
3 0 0 3

COURSE OUTCOMES

Upon completion of this course, the student will be able to

CO 1: outline the fundamentals of simulation and analysis of basic power electronic devices. (K2)
CO 2: develop the advanced algorithms in computer simulation. (K6)
CO 3: model the power electronic devices in simulation. (K3)
CO 4: infer the various analysis in simulation circuits. (K2)
CO 5: summarize the various case studies about the simulation of different power electronic devices. (K2)

UNIT I INTRODUCTION 9

Importance of simulation – General purpose circuit analysis – Methods of analysis of power electronic systems – Review of power electronic devices and circuits.

UNIT II ADVANCED TECHNIQUES IN SIMULATION 9

Analysis of power electronic systems in a sequential manner – Coupled and decoupled systems – Various algorithms for computing steady state solution in power electronic systems – Future trends in computer simulation.

UNIT III MODELING OF POWER ELCTRONIC DEVICES 9

Introduction – AC sweep and DC sweep analysis – Transients and the time domain analysis – Fourier series and harmonic components – BJT, FET, MOSFET and its model – Amplifiers and Oscillator – Non-linear devices.

UNIT IV SIMULATION OF CIRCUITS 9

Introduction – Schematic capture and libraries – Time domain analysis – System level integration and analysis – Monte Carlo analysis – Sensitivity/stress analysis – Fourier analysis.

UNIT V CASE STUDIES 9

Simulation of Converters – Choppers – Inverters – AC voltage controllers – and Cycloconverters feeding R, R-L, and R-L-E loads – Computation of performance parameters: harmonics – Power factor – Angle of overlap.

L :45 TOTAL:45 PERIODS

REFERENCES

1. Rashid M., “Simulation of Power Electronic Circuits using PSPICE”, PHI, 2006.
2. Rajagopalan V., “Computer Aided Analysis of Power Electronic systems” Marcell –Dekker Inc., 1987.
3. John Keown, “Microsim, Pspice and Circuit Analysis”- Prentice Hall Inc., 1998.

15HE22E ADVANCED ELECTRICAL DRIVES **L T P C**
3 0 0 3

COURSE OUTCOMES

Upon completion of this course, the student will be able to

CO 1: appraise about dc and ac electrical drives (K5)
CO 2: model the induction motor using reference frame theory
CO 3: outline the vector control techniques for ac drives (K2)
CO 4: explain about sensorless control techniques for electric drives (K5)
CO 5: list the various control techniques for special electrical machines. (K1)

UNIT I INTRODUCTION **9**

Review of dc drives and scalar control of AC drives – Disadvantages of scalar control of AC drives

UNIT II REFERENCE FRAME THEORY & MODELING OF INDUCTION MOTOR **9**

Space vector theory – Dynamic d-q modeling of induction machines – Stator, rotor and synchronously rotating reference, frame models, state space equations and dynamic simulation, – Space Phasor model – Control – Principle of the induction motor

UNIT III VECTOR CONTROL **9**

Vector controlled induction motor drive – Basic principle – Direct Rotor flux oriented vector control – Estimation of rotor flux and torque – Implementation with current source and voltage source inverters, Stator flux oriented vector control – Indirect rotor flux oriented vector control scheme implementation – Tuning – Dynamic simulation. Parameter sensitivity and compensation of vector controlled induction motors-Selection of Flux level – Flux weakening operation – Speed controller design – Direct torque control of Induction Motor – Vector control strategies for Synchronous motor.

UNIT IV SENSOR LESS CONTROL **9**

Principles for speed sensor less control - Sensor less methods for scalar control – Sensorless methods for vector control – Introduction to observer based techniques.

UNIT V SPECIAL MACHINES **9**

Brushless DC drives-principle – Performance and inverter control strategies – PMSM motor& synchronous reluctance motor: converter and driver configurations – Control scheme and performance characteristics – Linear induction motor – Hysterisis motor – Stepper motor – Principle, construction, operation and drive application – Energy conservation in Electrical drives.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. B.K. Bose, “Modern Power Electronics and AC Drives”, Pearson Education, 2002
2. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control”, Prentice-Hall India, NewDelhi, 2003
3. P. Vas, “Sensor less vector and direct torque control”, Oxford Press, 1992.
4. T.J.E. Miller, “Brushless Permanent-magnet and reluctance motor Drives” 1989.
5. Werner Leonhard, “Control of electrical drives”, Springer-2001.
6. D WNovotny and T A Lipo, “Vector Control and Dynamics of AC Drives”, Oxford University Press, 1996
7. Kazmierkowski, Krishnan, Blaabjerg, “Control in Power Electronics-Selected Problems”, Academic Press, 2002

15HE23E	SOFT COMPUTING TECHNIQUES *(Common to HVE and C&I)*	L T P C 3 0 0 3

COURSE OUTCOMES

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

CO 1: outline the concepts of intelligent expert system (K2).
CO 2: explain the components of fuzzy logic system (K5).
CO 3: distinguish various structures of ANN (K4).
CO 4: describe the basic concepts of genetic algorithms (K6).
CO 5: apply ANN, FLC and GA to various electrical applications (K3).

UNIT I INTRODUCTION 9

Approaches to intelligent control – Architecture for intelligent control – Symbolic reasoning system – rule – Based systems – AI approach – Knowledge representation – Expert systems.

UNIT II ARTIFICIAL NEURAL NETWORKS 9

Concept of Artificial Neural Networks and its basic mathematical model – McCulloch-Pitts neuron model – Simple perceptron – Adaline and Madaline – Feed-forward Multilayer Perceptron – Learning and Training the neural network – Data Processing: Scaling – Fourier transformation – Principal – Component analysis and wavelet transformations – Hopfield network, Self-organizing network and Recurrent network – Neural Network based controller.

UNIT III FUZZY LOGIC SYSTEM 9

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

UNIT IV GENETIC ALGORITHM 9

Basic concept of Genetic algorithm and detail algorithmic steps – Adjustment of free parameters – Solution of typical control problems using genetic algorithm – Concept on some other search techniques like tabu search and ant-colony search techniques for solving optimization problems.

UNIT V APPLICATIONS 9

GA application to power system optimization problem – Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab – Neural Network toolbox – Stability analysis of Neural –Network interconnection systems – Implementation of fuzzy logic controller using Matlab fuzzy – Logic toolbox – Stability analysis of fuzzy control systems.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Jacek M Zurada, "Introduction to Artificial Neural Systems", Jaico Publishing House, 1999.
2. Kosko.B, "Neural Networks And Fuzzy Systems", Prentice-Hall of India Pvt Ltd., 1994.
3. Klir G.J. and Folger T.A., "Fuzzy sets, Uncertainty and Information", Prentice-Hall of India Pvt. Ltd., 1993.
4. Zimmerman H.J., "Fuzzy set theory-and its Applications"-Kluwer Academic Publishers, 1994.
5. Driankov and Hellendroon, "Introduction to Fuzzy Control", Narosa Publishers, 2001

15HE24E ADVANCED DIGITAL SIGNAL PROCESSING L T P C
(Common to CS, HVE and C&I) **3 0 0 3**

COURSE OUTCOMES

Upon completion of the course, the students will be able to

CO 1: Discuss the essentials for the postgraduate level research in the area of statistical signal processing. (K1-K2)
CO 2: Model random signals and determine its solution. (K1-K3)
CO 3: Estimate the coefficient for perfect reproduction filter for both the stationary and non-stationary signals. (K1- K3)
CO 4: Design FIR and IIR adaptive filters using adaptive algorithms. (K1- K4)
CO 5: Estimate the power spectrum for discrete random signals using classical and non-classical methods. (K1- K3)

UNIT I DISCRETE RANDOM SIGNAL PROCESSING 9

Random Processes - Ensemble Averages, Gaussian processes, Stationary processes, Auto covariance and Autocorrelation matrices, Bias and Estimation, Parseval's theorem, Wiener-Khintchine relation, White noise, Power Spectral Density, Spectral factorization, Filtering Random Processes, Special types of Random Processes - ARMA, AR, MA.

UNIT II SIGNAL MODELING 9

Least Squares method, Pade approximations, Prony's method – Pole zero modeling, All pole modeling, Linear prediction, Forward and Backward prediction, Finite data records, stochastic models, Solution of Prony's normal equations – Levinson Durbin recursion.

UNIT III WIENER FILTERING 9

FIR Wiener filter – Filtering, Linear prediction, Noise cancellation, Lattice representation, Causal and Non-causal IIR Wiener filters, Weiner Deconvolution, Discrete Kalman filter.

UNIT IV ADAPTIVE FILTERS 9

FIR adaptive filters, Steepest Descent Adaptive Filter, LMS algorithm, Normalized LMS algorithm, Noise cancellation, Channel equalization, Adaptive Recursive filters, Recursive Least squares algorithm.

UNIT V SPECTRAL ESTIMATION 9

Nonparametric methods - Periodogram, Modified periodogram, Bartlett, Welch and Blackman-Tukey methods, Parametric methods - ARMA, AR and MA model based spectral estimation.

L:45 TOTAL: 45 PERIODS

REFERENCES

1. Monson H. Hayes, "Statistical Digital Signal Processing and Modeling", John Wiley and Sons, Inc, Singapore, 1st Edition, 2008.
2. John G. Proakis and Dimitris K Manolakis, "Digital Signal Processing", Pearson Education, 4th Edition, 2009.
3. Alan V. Oppenheim and Ronald W. Schafer, "Discrete-Time Signal Processing", 3rd Edition, Prentice Hall, 2009.
4. Emmanuel C. Ifeachor and Barrie W. Jervis, "Digital signal processing: A practical approach", 2nd Edition, Prentice Hall, 2002.

15HE25E EVOLUTIONARY COMPUTING **L T P C**
(Common to HVE and C&N) **3 0 0 3**

COURSE OUTCOMES

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

CO 1; explain the basic concepts of evolutionary computation. (K2)
CO 2: classify the various representations, selection and search operations (K2)
CO 3: discuss the basics of fitness evaluation and constraint handling mechanism. (K2)
CO 4: outline the concepts of hybrid systems. (K2)
CO 5: interpret the effect of parameter setting and applications. (K3)

UNIT I INTRODUCTION TO EVOLUTIONARY COMPUTATION 9

Introduction – Possible applications of evolutionary computations – History of evolutionary computation – Genetic algorithms – Evolution strategic – Evolutionary programming – Derivative methods – Stochastic processes – Modes of stochastic convergence – Schema processing – Transform methods – Fitness landscape – Probably Approximately Correct(PAC) learning analysis – Limitation of evolutionary computation methods – Local performance measures.

UNIT II REPRESENTATION, SELECTION AND SEARCH OPERATORS 9

Representation – Binary strings – Real-valued vectors – Permutations – Finite-state representation – Parse trees – Guidelines for a suitable encoding – Other representations Selection – Proportional selection and sampling algorithms – Tournament selection – Rank based selection – Boltz Mann selection – Other selection methods – Hybrids Generation gap methods – A comparison of selection mechanisms – Interactive evolution – Search Operators – Mutation – recombination – Other operators.

UNIT III FITNESS EVALUATION AND CONSTRAINT HANDLING 9

Fitness Evaluation – Encoding and decoding functions – Competitive fitness evaluation – Complexity based fitness evaluation – Multi objective optimization – Constraint handling techniques – Penalty functions – Decoders – Repair algorithms – Constraint preserving operators – Other constraint handling methods – Constraint satisfaction problems – Population structures – Niching Methods – Specification methods – Island(migration)models.

UNIT IV HYBRID SYSTEM 9

Self-adaptation – Meta evolutionary approaches – Neural – Evolutionary systems – New areas for evolutionary computation research in evolutionary systems – Fuzzy-Evolutionary Systems – Combination with Other Optimization Methods – Combination with local search – Combination with dynamic programming – Simulated annealing and tabu search – Comparison with existing optimization.

UNIT V PARAMETER SETTING AND APPLICATIONS 9

Heuristics for Parameter setting Issues – Population size – Mutation parameters – Recombination parameters – Implementation of Evolutionary Algorithms – Efficient implementation of algorithms – Computation time of evolutionary operators – Applications – Classical optimization problems – Control Identification – Scheduling – Pattern recognition – Simulation models.

L:45 TOTAL:45 PERIODS

REFERENCES

1. Thomas Back et al, "Handbook on evolutionary computation", Institute of Physics, Publishing, 2000.
2. Xin Yao, "Evolutionary Computations: Theory and Applications", World Scientific 39 Publishing, 1999.
3. Goldberg, "Genetic algorithm in search, optimization and machine learning", Addison Wesley, 1998.
4. Davis, "Hand book on Genetic Algorithms", NewYork, 1991.
5. Kenneth A De Jong, "Evolutionary Computation: A Unified Approach", MIT Press, 2006.

15HE26E	ADVANCED DIGITAL SYSTEM DESIGN	L T P C
	(Common to C&I and HVE)	3 0 0 3

COURSE OUTCOMES

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

CO 1: design a small digital system to the specified functionality. (K3)
CO 2: apply modern tools in combinational and sequential circuit design with VHDL. (K3)
CO 3: explain new generation programmable logic devices. (K2)
CO 4: apply testability algorithms in the design of digital circuits. (K3)

UNIT I 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.

UNIT II 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.

UNIT III 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.

UNIT IV SYSTEM DESIGN USING VHDL 9

VHDL operators – Arrays – concurrent and sequential statements – packages - Data flow – Behavioral – structural modeling – compilation and simulation of VHDL code – Test bench - Realization of combinational and sequential circuits using HDL – Registers – counters – sequential machine – serial adder – Multiplier - Divider – Design of simple microprocessor.

UNIT V NEW GENERATION PROGRAMMABLE LOGIC DEVICES 9

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

L: 45 TOTAL: 45 PERIODS

TEXT BOOKS

1. Donald G. Givone, "Digital principles and Design", Tata McGraw Hill 2001.
2. Stephen Brown and Zvonk Vranesic, "Fundamentals of Digital Logic with VHDL Design", Tata McGraw Hill Higher Education, 2009.

REFERENCES

1. Mark Zwolinski, "Digital System Design with VHDL", Pearson Education, 2001.
2. Parag K Lala, "Digital System design using PLD", BS Publications, 2001.
3. John M Yarbrough, "Digital Logic applications and Design", Thomson Learning, 2001.
4. Nripendra N Biswas, "Logic Design Theory", Prentice Hall of India, 2001.
5. Charles H. Roth Jr., "Fundamentals of Logic design", 6^{th} Edition, Thomson Learning, 2010.
6. Charles H Roth Jr. "Digital System Design using VHDL", Thomson learning, 2004.
7. Douglas L.Perry, "VHDL programming by Example", Tata McGraw Hill, 2006.

15HE27E DESIGN OF EMBEDDED SYSTEMS **L T P C**
(Common to C&I and HVE) **3 0 0 3**

COURSE OUTCOMES

Upon completion of the course, the students will be able to

CO 1 : explain the basic concepts and building blocks of embedded system. (K2)
CO 2 : infer the fundamentals of Embedded processor Modeling. (K2)
CO 3 : illustrate bus communication in processors and I/O interfacing. (K2)
CO 4 : summarize processor scheduling algorithms and to explain the basics of RTOS. (K2)
CO 5 : distinguish the different phases & modeling of embedded system with its applications on various fields. (K3)

UNIT I INTRODUCTION TO EMBEDDED SYSTEMS 9

Introduction to Embedded Systems -The build process for embedded systems - Structural units in Embedded processor-Selection of processor & memory devices- DMA –Memory management methods - Timer and Counting devices, Watchdog Timer, Real Time Clock-Software Development tools-IDE, assembler, compiler, linker, simulator, debugger-In circuit emulator, Target Hardware Debugging, Boundary Scan.

UNIT II HARDWARE SOFTWARE PARTITIONING 9

Hardware / Software Co-Design-Basic concepts-Goals-Issues in Co-Design Models - Finite state Machine - HFSM-PSM-Architectures control / data flow nets, task graphs - Generic Co-Design Methodology – Approaches - Challenges, System Specification languages - State charts and modeling - Single processor Architectures - Hardware / Software duality - HW/SW portioning- Algorithm development - Prototyping & emulation technique.

UNIT III EMBEDDED NETWORKING AND INTERRUPTS SERVICE MECHANISM 9

Embedded Networking: Introduction, I/O Device Ports & Buses-Serial Bus communication protocols - RS232 standard-RS485-CAN Bus-Inter Integrated Circuits (I2C)-Interrupt sources ,Programmed I/O-Busy-wait approach without interrupt service mechanism-ISR concept-Multiple interrupts-Context and periods for context switching, interrupt latency and deadline-Device Driver-Introduction to Basic Concept of Parallel port & Serial port Device Drivers.

UNIT IV RTOS BASED EMBEDDED SYSTEM DESIGN 9

Introduction to basic concepts of RTOS-Need, Task, process & threads, interrupt routines in RTOS-Multiprocessing and Multitasking- Preemptive and non-preemptive scheduling-Task Communication - Shared memory - Message passing – Inter process Communication- Synchronization between processes-Semaphores-Mailbox-Pipes-Priority inversion-Priority inheritance-Comparison of Real time Operating systems: VxWorks, µC/OS-II, RT Linux.

UNIT V EMBEDDED SYSTEM APPLICATION DEVELOPMENT WITH PROCESSOR 9

Objective, Need, different Phases & Modelling of the EDLC-Choice of Target Architectures for Embedded Application Development for Control Dominated-Data Dominated Systems-Case studies on Digital Camera, Adaptive Cruise control in a Car, Mobile Phone software for key inputs.

L : 45 TOTAL : 45 PERIODS

TEXT BOOKS

1. Rajkamal, “Embedded system-Architecture, Programming, Design”, Tata Mcgraw Hill, 2011.
2. Shibu.K.V, “Introduction to Embedded Systems”, Tata Mcgraw Hill, 2009.

REFERENCES

1. Peckol, “Embedded system Design”,John Wiley & Sons,2010.
2. Lyla.B.Das, “Embedded Systems-An Integrated Approach”, Pearson, 2013.
3. Elicia White, “Making Embedded Systems”, O’ Reilly Series, SPD, 2011.
4. Tammy Noergaard, “Embedded System Architecture, A comprehensive Guide for Engineers and Programmers”, Elsevier, 2006.
5. Prasad.K.V.K.K., “Embedded / Real-Time Systems-Concepts, Design & Programming-Black Book”, Dream tech Press, 2010.

15HE28E APPLICATIONS OF MEMS TECHNOLOGY **L T P C**
3 0 0 3

COURSE OUTCOMES

Upon completion of this course, students will be able to

CO 1: explain the basic of fabrication processes and electro mechanical concepts.(K2)
CO 2: illustrate electrostatic sensors, actuators and its applications. (K2)
CO 3: outline the concepts of thermal sensing and actuation techniques. (K2)
CO 4: discuss the concepts of piezoelectric sensing and actuation techniques. (K6)
CO 5: Summarize the various case studies in MEMS technology. (K2)

UNIT I MICRO-FABRICATION, MATERIALS AND ELECTRO-MECHANICAL CONCEPTS 9

Overview of micro fabrication – Silicon and other material based fabrication processes – Concepts – Conductivity of semiconductors – Crystal planes and orientation – Stress and strain – Flexural beam bending analysis – Torsional deflections – Intrinsic stress – Resonant frequency and quality factor.

UNIT II ELECTROSTATIC SENSORS AND ACTUATION 9

Principle – Material – Design and fabrication of parallel plate capacitors as electrostatic sensors and actuators – Applications

UNIT III THERMAL SENSING AND ACTUATION 9

Principle – Material – Design and fabrication of thermal couples – Thermal bimorph sensors – Thermal resistor sensors – Applications.

UNIT IV PIEZOELECTRIC SENSING AND ACTUATION 9

Piezoelectric effect – Cantilever piezoelectric actuator model – Properties of piezoelectric materials – Applications.

UNIT V CASE STUDIES 9

Piezoresistive sensors – Magnetic actuation – Micro fluidics applications – Medical applications – Optical MEMS.

L:45 TOTAL:45 PERIODS

REFERENCES

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
2. Marc Madou, “Fundamentals of Microfabrication”, CRC Press, 2009.
3. Boston, “Micromachined Transducers Sourcebook”, WCB Tata McGraw-Hill, 1998.
4. Bao M.H., “Micromechanical transducers: Pressure sensors, accelerometers and gyroscopes”, Elsevier, Newyork, 2000

15HE29E MICROCONTROLLER AND DSP BASED SYSTEM DESIGN **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the architecture, addressing modes and programming techniques of PIC 16C7X microcontroller. (A3)
CO 2: discuss the various peripherals of 16C7X microcontroller. (K6)
CO 3: illustrate the architecture, addressing modes and programming techniques of motor control signal processors. (K2)
CO 4: list the various peripherals of motor control signal processors. (K1)
CO 5: outline the applications of 16C7X microcontroller and motor control signal processors. (K2)

UNIT I PIC 16C7X MICROCONTROLLER 9

Architecture memory organization – Addressing modes – Instruction set – Programming techniques – Simple programs.

UNIT II PERIPHERALS OF PIC 16C7X 9

Timers – Interrupts – I/O ports – I2C bus for peripheral chip access – A/D converter –UART.

UNIT III MOTOR CONTROL SIGNAL PROCESSORS 9

Introduction – System configuration registers – Memory Addressing modes – Instruction set – Programming techniques – Simple programs.

UNIT IV PERIPHERALS OF SIGNAL PROCESSORS 9

General Purpose Input/Output (GPIO) Functionality – Interrupts – A/D converter – Event Managers (EVA, EVB) – PWM signal generation.

UNIT V APPLICATIONS OF PIC AND SIGNAL PROCESSORS 9

Voltage regulation of DC-DC converters – Stepper motor and DC motor control – Clarke's and parks transformation – Space vector PWM – Control of Induction Motors and PMSM.

L:45 TOTAL:45 PERIODS

REFERENCES

1. John B Peatman, "Design with PIC Microcontrollers", Pearson Education, Asia, 2004.
2. Hamid A Toliyat, Steven Campbell, "DSP based Electromechanical Motion Control", CRC Press, 2004.

15HE30E OPTIMIZATION TECHNIQUES **L T P C**
3 0 0 3

COURSE OUTCOMES

Upon completion of this course, students will be able to

CO 1: outline the basic concepts of optimization problems (K2)
CO 2: perform optimization using linear and non linear programming. (S2)
CO 3: make use of integer, stochastic and geometric programming for optimization Problems (K4)
CO 4: summarize various direct search techniques in optimization techniques (K2)

UNIT I INTRODUCTION 9

Engineering Applications of optimization – statement of an optimization problem – Classification of optimization problems.

UNIT II LINEAR AND NON LINEAR PROGRAMMING 9

Linear programming, Simplex algorithm – Duality – Revised simplex algorithm – Sensitivity analysis. Non linear programming: Unconstrained optimization – Gradient based methods – Newton's method – Quasi Newton's method – Constrained optimization – Penalty function methods.

UNIT III INTEGER, STOCHASTIC AND GEOMETRIC PROGRAMMING 9

Integer Programming- Introduction – Formulation – Gomory cutting plane algorithm – Zeroor one algorithm, branch and bound method.
Stochastic Programming: Basic concepts of probability theory – Random variables distributions mean – Ariance – Correlation – Co variance – Joint probability distribution – Stochasticlinear – Dynamic programming.
Geometric Programming: Posynomials – Arithmetic – Geometric inequality – Unconstrained G.P- Constrained G.P

UNIT IV DIRECT SEARCH TECHNIQUES - I 9

Univariate methods – Pattern search methods – Branch and bound method for mixed integer problems – Simulated annealing – Tabu search.

UNIT V DIRECT SEARCH TECHNIQUES - II 9

Genetic algorithm – Particle swarm optimization – Ant colony optimization – Differential evolution techniques – Multi objective optimization – Pareto solutions.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. S.S.Rao, "Optimization theory and Applications", New Age International, 1984.
2. Kalyanmoy Deb, "Optimization for Engineering Design", PHI, 2012.
3. S.D.Sharma, "Operations Research – Theory and Applications", Macmillan Publications, 2009.
4. H.A.Taha , "Operation Research", TMH, 1982.
5. R.LRardin, "Optimization in operations research", Pearson New International, 2014.
6. Belagundu & Chandraputla, "Optimization Concepts and Applications in Engineering", Pearson Asia, 2011.
7. M.C.Joshi, K.M.Moudgalya, "Optimization Techniques theory and practice", Narosa Publications, 2004.

15HE31E WIND ENERGY CONVERSION SYSTEMS L T P C
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain about the fundamentals of wind energy conversion systems.(K5)
CO 2: illustrate the wind turbine concept with its design considerations. (K2)
CO 3: develop the model of fixed speed system for WECS. (K6)
CO 4: discuss about the variable speed system and the various generator used in WECS. (K6)
CO 5: analyze the Grid connected WECS and its controller. (K4)

UNIT I INTRODUCTION 9

Components of WECS – WECS schemes – Power obtained from wind – Simple momentum theory –Power coefficient – Sabinin's theory – Aerodynamics of wind turbine.

UNIT II WIND TURBINES 9

HAWT – VAWT – Power developed – Thrust – Efficiency – Rotor selection – Rotor design considerations – Tip speed ratio – No. of Blades – Blade profile – Power Regulation – Yaw control –Pitch angle control – Stall control – Schemes for maximum power extraction.

UNIT III FIXED SPEED SYSTEMS 9

Generating Systems – Constant speed constant frequency systems – Choice of Generators – Deciding factors – Synchronous Generator – Squirrel Cage Induction Generator – Model of Wind Speed – Model wind turbine rotor – Drive Train model – Generator model for Steady state and Transient stability analysis.

UNIT IV VARIABLE SPEED SYSTEMS 9

Need of variable speed systems – Power-wind speed characteristics – Variable speed constant frequency systems synchronous generator – DFIG – PMSG – Variable speed generators modeling – Variable speed variable frequency schemes

UNIT V GRID CONNECTED SYSTEMS 9

Stand alone and Grid Connected WECS system – Grid connection Issues – Machine side & Grid side controllers – WECS in various countries.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Freris L.L., "Wind Energy conversion Systems", Prentice Hall, 1990.
2. Ion Boldea, "Variable speed generators", Taylor & Francis group, 2006.
3. Golding E.W., "The generation of Electricity by wind power", Redwood burn Ltd.,Trowbridge, 1976.
4. Heir S.,"Grid Integration of WECS", Wiley 1998.
5. Rai G.D., "Non-conventional Sources of Energy", Khanna publishers, Fourth Edition, 2009

15HE32E ENERGY MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO 1: analyze the energy economics with energy auditing (K4)
CO 2: estimate the electrical energy calculation. (K6)
CO 3: discuss about the energy conservation methods. (K6)
CO 4: select the proper electrical utilities. (A3)
CO 5: describe the concepts of energy management (A1)

UNIT I INTRODUCTION 9

Concept of energy management – Elements of energy management – Energy cost – Energy performance – Energy saving calculations – Balancing energy use and requirement – Maximizing system efficiencies – Optimizing input energy requirement – Demand Side Management – Harmonics in supply system – Voltage Sag – Power Factor. Reliability analysis of power system

UNIT II ECONOMIC ASPECTS OF ENERGY AUDIT 9

Cost evaluation by ROI – IRR Cost evaluation by payback terms – Organization for energy management – Conservation measures and diagnostic review.

UNIT III ENERGY AUDIT & CASE STUDIES 9

Introduction – Types and walkthrough energy audit – Energy audit at unit level – Industrial Audit approaches – Procedure for energy audit and equipments required – Comprehensive Energy audit Site testing – Measurement & Analysis of Electrical System like Induction Motors – Transformers – Synchronous Machines – Illumination system – DomesticAppliances Site testing Measurement & Analysis of Electrical System like Boilers – Furnaces – Refrigeration and Air-conditioning System

UNIT IV THE ELECTRIC UTILITY IN INDUSTRY 9

Introduction – Electric utilities characterized by function – Different regulated electric utility frameworks – “Electric Utility” structure inderegulated industry – Energy conservation task in industry – Co generation – Energy conservation in cement – Textile, sugar, etc. – Industry Energy conservation in building.

UNIT V MODERN ENERGY EFFICIENT TECHNOLOGIES 9

Maximum demand controller – Automatic power factor controller – Energy efficient motors – Soft starters with energy saver – Energy efficient transformers – Electronic ballast – Occupancy sensors etc. Energy efficientlightning controls – Energy saving in transportation system especially electric vehicle – Energy saving in air conditioning system.

L:45 TOTAL: 45 PERIODS

REFERENCES

1. Barney. L Capehart, William J. Kennedy, Wayne C. Turner, “Guide to Energy Management”, Taylor & Francis, 2007.
2. S. Rao, “Energy Technology”Khanna Publishers, 3rd Edition, 1999.
3. K. Nagabhushan Raju, “Industrial Energy Conservation Techniques: Concepts, Applications and Case studies”, Atlantic publisher, 2007
4. Harry B. Zackrison, “Energy conservation techniques for engineers”, Van Nostrand Reinhold, 1984.
5. Penni McLean-Conner, “Energy Efficiency: Principles and Practices”, Pennwell corporation, 2009.
6. Steven R. Patrick, Dale R. Patrick, Stephen W. Fardo, “Energy Conservation Guidebook”, Fairmont Press, 1993.
7. Course Material for Accredited Energy Managers and Energy Auditors – Bureau ofEnergy Efficiency
8. www.energymanagertraining.com,
9. www.bee-india.gov.in

15HE33E FUNDAMENTALS OF NANO TECHNOLOGY

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO 1: explain crystal lattice structures. (K5)
CO 2: memorize the heterostructures and quantum structures.(S1)
CO 3: discuss the fabrication of nano structures. (K6)
CO 4: describe the characterization techniques.(A1)
CO 5: apply the nano technology in science and engineering. (K3)

UNIT I CRYSTALLINE PROPERTIES OF SOLID 9

Crystal lattice and seven crystal systems – Unit cell concept – Weigner-Seitz cell – Bravais lattices – Space and point groups – Miller indices – Reciprocal lattice – Brillouin zone.

UNIT II SEMICONDUCTOR HETEROSTRUCTURES AND LOW DIMENSIONAL QUANTUM STRUCTURES 9

Energy bands, Application of model solid theory – Anderson model for hetero junctions – Multiple quantum wells (MQWs) and super lattices – Two-dimensional nanostructure: quantum well – One dimensional nanostructure: quantum wire – Zero-dimensional nanostructure: quantum dot – Optical properties of low-dimensional structures – Examples and applications in real world.

UNIT III FABRICATION OF NANO STRUCTURES 9

Basic compound semiconductors – Bulk single crystal growth techniques – Epitaxial growth techniques – Physical vapour deposition and sputtering – Thermodynamics and kinetics of growths – Nano scale growth modes.

UNIT IV CHARACTERIZATION TECHNIQUES (Qualitative Treatment only) 9

Structural X-ray diffraction – Electron microscopy – Energy dispersive analysis using X-rays – X-ray photoelectron spectroscopy – Scanning probe microscopy – Optical – Photoluminescence spectroscopy – Absorbance measurement – Raman spectroscopy – Fourier transform spectroscopy.

UNIT V APPLICATIONS OF NANO TECHNOLOGY 9

Future of semiconductor device and research – Necessity of innovative technology and prospect for future – Applications in food, energy, transportation, communication, entertainment, health and medicine.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. M. Razeghi, "Fundamentals of Solid State Engineering", 2nd Edition, Springer, 2006.
2. K.K.Chattopadhyay, A.N. Banerjee, "Introduction to Nanoscience and Nanotechnology", PHI Learning Private Limited, 2011.
3. W. R. Fahrner, "Nanotechnology and Nano electronics: Materials, Devices, Measurement Techniques", Springer-Verlag Berlin Heidelberg, 2005
4. R. W. Kelsall, I. W. Hamley, and M. Geoghegan, "Nano scale Science and Technology", John Wiley & Sons Limited, England, 2005
5. M.A.Shah, Tokeer Ahmad, "Principles of Nano science and Nanotechnology", Narosa Publishing home Private Limited, 2010.
6. B.Viswanathan, "Nano materials", Narosa Publishing home Private Limited, 2009.
7. William Illsey Atkinson, "Nanotechnology", Jaico Publishing Home, 2008.

15HE34E SYSTEM THEORY **L T P C**
(Common to C&I and HVE) **3 0 0 3**

COURSE OUTCOMES

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

CO 1 : explain the state space models for a linear system. (K2)
CO 2 : analyse the state space model with respect to observability and stabilizability. (K4)
CO 3 : apply state variable feedback to place system poles. (K3)
CO 4 : discuss state variable observers and controllers. (K2)
CO 5 : apply lyapunou stability methods to solve linear problems. (K3)

UNIT I MODERN CONTROL THEORY 9

Limitations of conventional control theory - Concepts of State, State variables and State model – State model for linear time invariant systems: State space representation using physical-Phase and canonical variables.

UNIT II SYSTEM RESPONSE 9

Transfer function from state model - Transfer matrix - Decomposition of transfer functions Direct, Cascade and Parallel decomposition techniques - Solution of state equation - State transition matrix computation.

UNIT III SYSTEM MODELS 9

Characteristic equation - Eigen values and Eigen vectors - Invariance of Eigen values - Diagonalization - Jordan Canonical form - Concepts of Controllability and Observability - Kalman's and Gilbert's tests - Controllable and Observable phase variable forms - Effect of pole-zero cancellation on Controllability and Observability.

UNIT IV MODEL CONTROL 9

Introduction – Stability improvement by State Feedback – Necessary and sufficient conditions for Arbitary Pole Placement - Pole Placement by State Feedback - Full-Order Observers - Reduced-Order Observers - Deadbeat Control by State Feedback - Deadbeat Observers.

UNIT V LIAPUNOV STABILITY 9

Liapunov Stability analysis - Stability in the sense of Liapunov - Definiteness of Scalar Functions – Quadratic forms - Second method of Liapunov - Liapunov stability analysis of linear time invariant systems.

L: 45 TOTAL: 45 PERIODS

TEXT BOOKS

1. Gopal .M, “Modern Control System Theory”, 2nd Edition, New Age International Publisher, New Delhi, 2006.
2. Gopal M, “Digital Control and State Variable Methods”, 4th Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, India, 2003.

REFERENCES

1. Katsuhiko Ogata, "Modern Control Engineering", 3rd Edition, Prentice Hall of India Private Ltd., New Delhi, 2002.
2. Nagrath I J and Gopal M, "Control Systems Engineering", New Age International Publisher, New Delhi, 2006.
3. Nise S Norman, “Control Systems Engineering”, 3rd Edition, John Wiley & Sons, Inc, Delhi, 2000.
4. Benjamin C Kuo, “Automatic Control Systems”, John Wiley & Sons, Inc., Delhi, 2002

15HE35E PC BASED INSTRUMENTATION SYSTEM DESIGN **L T P C**
(Common to C&I and HVE) **3 0 0 3**

COURSE OUTCOMES

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

CO 1 : describe the main functional units in a PC and the software used. (K2)
CO 2 : explain the architecture of PC expansion bus and USB. (K2)
CO 3 : differentiate PC expansion bus and USB. (K2)
CO 4 : select a Virtual Instrument for a particular application. (K3)
CO 5 : describe the functional units of a system for an application. (K2)

UNIT I PC AND ITS PROGRAMMING 9

Microcomputer systems - Data representation - Bus expansion - Microprocessor operation - Data transfer and control - Parallel versus serial I/O. PC memory - Memory operation - Memory organization - Data integrity - Memory terminology - Memory size - Memory speed - CMOS memory - BIOS ROM - PC memory allocation - BIOS data area - Disk drives. Choice of language - Software development - Control structures - Loops - Error checking and input validation – Event - driven programs - Testing.

UNIT II PC EXPANSION BUS SYSTEMS 9

Expansion methods - Development of PC expansion bus architectures - PC ISA/EISA expansion bus - PC expansion cards - Industry Standard Architecture (ISA) bus - The 62-way ISA (PC expansion bus) connector - The 36-way EISA (PC-AT expansion bus) connector - Electrical characteristics - Design of PC expansion cards - The PC/104 bus - Peripheral Component Interconnect/Interface (PCI) bus - Accelerated Graphics Port (AGP).

UNIT III THE UNIVERSAL SERIAL BUS 9

USB applications and principal features - USB implementation - Connection and disconnection of USB devices - USB bus topology and physical connections - Error detection and handling - USB data transfers - USB devices - USB data flow model - USB physical interface - Representative I/O cards - Measurement Computing Corporation PDISO-8 - Blue chip technology AIP-24 - Measurement Computing Corporation Dual-422 - Arcom APCI-ADADIO multifunction I/O card - The PMD-1208LS USB device.

UNIT IV VIRTUAL INSTRUMENTS 9

Selecting a virtual instrument - Instrument types - Instrument connection options - Digital storage oscilloscopes - Sampling rate and bandwidth - Resolution and accuracy - Low-cost DSO - High-speed DSO - High-resolution DSO - Choosing a computer-based DSO - Basic operation of a DSO - Waveform display - Parameter measurement - Spectrum analysis - Sound card oscilloscopes - Windows Oscilloscope - Software Oscilloscope - Waveform display - Parameter measurement - Spectrum analysis

UNIT V APPLICATIONS 9

Expansion cards - Approaches - PC instruments - Industrial PC systems - Backplane bus-based systems - Networked/distributed PC systems - Specifying hardware and software - Hardware design - Software design. Applications - Monitoring oscillator stability - Testing crystal filters - A speech enunciator - Strain measurement and display - Backup battery load test - Load sequencer - Environmental monitoring - Icing flow tunnel.

L: 45 TOTAL: 45 PERIODS

TEXT BOOK

1. Mike Tooley, “PC Based Instrumentation and Control”, Elsevier Publications, 3rd Edition, 2013.

REFERENCES

1. N. Mathivanan, “PC-Based Instrumentation:Concepts and Practice”, PHI Learning Private Limited, 2007.
2. Jovitha Jerome, “Virtual Instrumentation using Labview”, PHI Learning Pvt. Limited, 2010.
3. MAPLE V programming guide.
4. MATLAB/SIMULINK user manual.
5. MATHCAD/VIS SIM user manual.
6. LABVIEW simulation user manual

15HE36E ANALYSIS OF ELECTRICAL MACHINES

L	T	P	C
3	0	0	3

COURSE OUTCOMES

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

CO 1: describe the concepts of electromechanical energy conversion (A1)

CO 2: discuss the fundamentals of reference frame and its transformation (K6)

CO 3: evaluate the steady state and dynamic characteristic of DC machines (K5)

CO 4: analyze the steady state and dynamic characteristic of Induction Machines using reference frame variables (K4)

CO 5: recognize the steady state analysis, dynamic characteristic with computer simulation (A4)

UNIT I PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9

General expression of stored magnetic energy – Coenergy and force/ torque – Single and doubly excited system – Calculation of air gap mmf and per phase machine inductance using physical machine data.

UNIT II 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.

UNIT III DC MACHINES 9

Voltage and torque equations – Dynamic characteristics of permanent magnet and shunt DC motors – State equations – Solution of dynamic characteristic by Laplace transformation.

UNIT IV INDUCTION MACHINES 9

Voltage and torque equations – Transformation for rotor circuits – Voltage and torque 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.

UNIT V 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.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Paul C. Krause, OlegWasyzczuk, Scott S., and Sudhoff, "Analysis of Electric Machinery and Drive Systems", IEEE Press, 2nd Edition, 2002.
2. Krishnan R., "Electric Motor Drives, Modeling, Analysis and Control", Prentice Hall of India, 2002.
3. Samuel Seely, "Electromechanical Energy Conversion", Tata McGraw-Hill Publishing Company, 1962.
4. Fitzgerald A.E., Charles Kingsley, Jr, and Stephan D. Umanx, "Electric Machinery", Tata McGraw-Hill, 5th Edition, 1992.

15HE37E SPECIAL ELECTRICAL MACHINES L T P C
3 0 0 3

COURSE OUTCOMES

Upon completion of this course, students will be able to

CO 1: explain the construction, operation and the drive systems for stepper motor. (K2)
CO 2: analyze the construction, operation and controller for Switched Reluctance Motor.(K4)
CO 3: illustrate the constructional based types, operation and characteristics of Synchronous reluctance motor. (K2)
CO 4: develop the knowledge in construction, principle of operation, control techniques & its characteristics of PMSM. (K6)
CO 5: appraise the construction, principle of operation and control of Permanent Magnet BLDC motor. (K5)

UNIT I STEPPING MOTOR 9

Constructional features – Principle of operation – Modes of excitation – Torque production in variable reluctance stepping motor – Dynamic characteristics – Drive systems and circuit for open loop control – Closed loop control of stepping motor.

UNIT II SWITCHED RELUCTANCE MOTORS 9

Constructional features – Principle of operation – Torque equation – Power controllers – Characteristics and control – Microprocessor based controller.

UNIT III SYNCHRONOUS RELUCTANCE MOTORS 9

Constructional features: axial and radial air gap Motors – Operating principle – Reluctance torque – Phasor diagram – Motor characteristics.

UNIT IV PERMANENT MAGNET SYNCHRONOUS MOTORS 9

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

UNIT V 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 – Microprocessors based controller

L: 45 TOTAL: 45 PERIODS

REFERENCES

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. Krishnan R., “Switched Reluctance Motors Drives: Modeling, Simulation, Analysis Design and Applications”, CRC Press, New York, 2010

15HE38E CONDITION MONITORING OF HIGH VOLTAGE POWER APPARATUS **L T P C**
3 0 0 3

COURSE OUTCOMES

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

CO 1: explain the general concept of condition monitoring of high voltage power apparatus. (K5)
CO 2: illustrate the condition monitoring in power transformer. (K2)
CO 3: perform the power generation condition monitoring.(S2)
CO 4: distinguish the idea of various diagnostic techniques and condition monitoring. (K4)
CO 5: outline the insulation materials in application area and various testing techniques. (K2)

UNIT I INTRODUCTION 9

General concept of condition monitoring – General issues of condition monitoring – Main Components in a condition monitoring system – Condition monitoring techniques.

UNIT II POWER TRANSFORMER CONDITION MONITORING 9

Transformer faults and monitoring techniques – Monitoring for on-load tap changer – Insulation monitoring – Sweep frequency response test for condition monitoring – Recent trend/research on Power transformer condition monitoring.

UNIT III POWER GENERATION CONDITION MONITORING 9

Power generation faults and monitoring methods – Stator winding faults – Rotor body faults – Rotor winding faults – Stator-core faults – Condition monitoring for generator stator windings.

UNIT IV DIAGNOSTICS AND CONDITION MONITORING 9

Need for diagnostics and condition monitoring – On-line/on-site testing – Diagnostic tests – Digital techniques – Data acquisition principles and problems – Digital PD measurement – PD as a diagnostic tool – PD pattern – Noise reduction methods – Fault discrimination.

UNIT V INSULATION MATERIALS AND SYSTEMS 9

Outdoor insulation: Materials, ageing, diagnostic, polymeric materials, semi-conducting, Ceramic glazes – AC and impulse voltage flashover studies on a string of insulators – RIV and Corona Studies on insulator strings – High voltage testing – Dry, wet and pollution testing.

L: 45 TOTAL: 45 PERIODS

REFERENCES

1. Naidu M. S. and Kamaraju V., “High Voltage Engineering”, Tata McGraw-Hill, 1995.
2. Kulkarni S.V. and Khaparde S.A., “Transformer Engineering”, Marcel and Dekker Inc., 2004.
3. Tavner P. J. and Penman J., “Condition Monitoring of Electrical Machine”, Letchworth, England,Research Studies Press, Ltd., 1987.
4. Kuffel E., Zaengl W.S. and Kuffel L., “High Voltage Engineering Fundamentals,” Butterworth Heimann, 2nd Edition, 2000.
5. Rao B. K. N., “Handbook of Condition Monitoring”, Elsevier Science Publisher, 1st Edition, 1996.
6. Han Y. and Song Y. H., “Condition Monitoring Techniques for Electrical Equipment – A Literature Survey.” IEEE Trans. on Power Delivery, Vol. 18, No. 1, January 2003.
7. Wadhwa C. L., “High Voltage Engineering”, Wiley Eastern Limited, New Delhi, 1994