ACADEMIC REGULATIONS COURSE STRUCTURE AND DETAILED SYLLABUS

ELECTRICAL AND ELECTRONICS ENGINEERING

for

M.Tech. – HIGH VOLTAGE ENGINEERING

(Applicable from 2016-2017 Batches)

UNIVERSITY COLLEGE OF ENGINEERING KAKINADA
(Autonomous)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA

KAKINADA - 533 003, ANDHRA PRADESH, INDIA

COURSE STRUCTURE

I Semester

S. No.	Subject	L	P	Credits
1	Generation and Measurement of High Voltages	4	--	3
2	Dielectric and Insulation Engineering	4	--	3
3	HVDC Transmission	4	--	3
4	Power System Operation and Control	4	--	3
5	Elective – I i. Artificial Intelligence Techniques ii. Advanced Digital Signal Processing iii. Smart Grid Technologies iv. Breakdown Phenomenon in Electrical Insulation	4	--	3
6	Elective – II i. High Voltage Power Apparatus & Diagnostics ii Collision Phenomena in Plasma Science iii. Advanced EM Fields	4	--	3
7	High Voltage Laboratory	--	4	2
Total Credits				**20**

II Semester

S. No.	Subject	L	P	Credits
1	High Voltage Testing Techniques	4	--	3
2	EHVAC Transmission	4	--	3
3	Surge Phenomenon & Insulation Coordination	4	--	3
4	Advanced Power System Protection	4	--	3
5	Elective – III i. Partial Discharge in HV Equipment ii. Gas Insulated Systems and Substations iii. Pulse Power Engineering	4	--	3
6	Elective – IV i. Flexible AC Transmission Systems ii.Power System Deregulation iii.Reactive Power compensation & Management	4	--	3
7	Simulation Laboratory	--	4	2
Total Credits				**20**

III Semester

S. No.	Subject	L	P	Credits
1	Comprehensive Viva-Voce	--	--	2
2	Seminar – I	--	--	2
3	Project Work - I	--	--	16
Total Credits				**20**

IV Semester

S. No.	Subject	L	P	Credits
1	Seminar – II	--	--	2
2	Project Work - II	--	--	18
Total Credits				**20**

I-I

GENERATION & MEASUREMENT OF HIGHVOLTAGES
(Common to AEPS & HVE)

L / P / Credits
4 / -- / 3

Prerequisites: Basicsof Electrical circuits, Electronics and measurements for testing purpose

Course Educational Objectives:

- To study the numerical methods for analyzing electrostatic field problems.
- To study the fundamental principles of generation of high voltage for testing.
- To study the methods for measurement of high AC, DC and transient voltages.
- To Study the measurement techniques for high AC, DC and impulse currents.

Unit 1- Electrostatic fields and field stress control: Electric fields in homogeneous Isotropic materials and in multi dielectric media-Simple configurations-field stress control. Methods of computing electrostatic fields-conductive analogues-Impedance networks Numerical techniques-finite difference method-finite element method and charge simulation method.

Unit 2-Generation of High AC & DC Voltages:
Direct Voltages: AC to DC conversion methods electrostatic generators-Cascaded Voltage Multipliers.
Alternating Voltages: Testing transformers-Resonant circuits and their applications, Tesla coil.

Unit 3-Generation of Impulse Voltages :
Impulse voltage specifications-Impulse generations circuits-Operation, construction and design of Impulse generators-Generation of switching and long duration impulses.
Impulse Currents : Generation of High impulse currents and high current pulses.

Unit 4- Measurement of High AC & DC Voltages :
Measurement of High D.C. Voltages : Series resistance meters, voltage dividers and generating voltmeters.
Measurement of High A.C. Voltages : Series impedance meters electrostatic voltmeters potential transformers and CVTS-voltage dividers and their applications.

Unit 5-Measurement of Peak Voltages : Sphere gaps, uniform field gaps, rod gaps.Chubb-Fortesque methods.Passive and active rectifier circuits for voltage dividers.
Measurement of Impulse Voltages : Voltage dividers and impulse measuring systems-generalized voltage measuring circuits-transfer characteristics of measuring circuits-L.V. Arms for voltage dividers-compensated dividers.
Measurement of Impulse Currents : Resistive shunts-current transformers-Hall Generators and Faraday generators and their applications-Impulse Oscilloscopes.

Course Outcomes:

After completion of the course the student will be able to:

- Understand numerical computation of electrostatic problems.
- Understand the techniques of generation of high AC, DC and transient voltages.
- Measure high AC, DC and transient voltages.
- Measure high AC, DC and transient currents.

Reference Books :

1. High Voltage Engineering – by E.Kuffel and W.S.Zaengl. Pergaman press Oxford, 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Mc.Graw-Hill Books Co., New Delhi, 2nd edition, 1995.
3. High Voltage Technology – LL Alston, Oxford University Press 1968.
4. High Voltage Measuring Techniques – A. Schwab MIT Press, Cambridge,USA, 1972.
5. Relevant I.S. and IEC Specifications.

I-I

DIELECTRICS AND INSULATION ENGINEERING

L / P / Credits
4 / -- / 3

Prerequisites: Concepts of High voltage engineeringand basic physics.

Course Educational Objectives:

- To understand the electrical properties of insulating materials.
- To understand the principles of dielectric failure in insulating materials.
- To understand the application of insulating materials in different electrical apparatus.

Unit 1-Dielectrics and Insulating Materials: Review of Dielectric Phenomenon: Complex permittivity – Polarization - Relaxation and resonant models. Solid, Liquid and Gaseous insulating materials-Physical, Thermal & Electrical properties-Classification of Insulating Materials.

Unit 2-Solid Insulating Materials: Organic Fiber materials Ceramics & Synthetic polymers and their applications.
Liquid Insulating Materials: Insulating oils, their properties and applications.
Gaseous Insulating Materials: Air and SF_6- applications in electrical apparatus.

Unit 3-Breakdown phenomenon in gaseous and vacuum insulation: Insulation and decay processes-transition from self-sustained discharges to breakdown-Townsend and streamer discharge Paschen's law,Penning effect-Time lags-Surge breakdown voltage-Breakdown an non uniform fields-Vacuum insulation and vacuum breakdown.

Unit 4-Breakdown Phenomenon in Liquid and Solid Insulation: pure and commercial liquids-suspended particle and bubble theories-stressed oil volume theory-Breakdown in solid insulation Intrinsic breakdown-Treeing and tracking phenomenon-Thermal breakdown—Breakdown in composite dielectrics.

Unit 5-Insulation Engineering: Insulation design for power cables, capacitors, bushings, switchgear, transformers and rotating machines-resents trends.

Course Outcomes:

After completion of the course, students will be able to:

- Properties of insulating materials.
- Electrical breakdown in gas and vaccum insulation.
- Electrical breakdown in liquid and solid insulation.
- Insulation design in electrical power apparatus.

Reference Books:

1. High Voltage Engineering – by E.Kuffel and W.S. ZaegnlPergamon press, Oxford, 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Tata McGraw-Hill Books Co., New Delhi, 2nd edition, 1995.
3. Electrical Engineering Materials – B. Tareev, M.I.R. Publications, MOSCOW.
4. Physics of Dielectrics - B. Tareev, M.I.R. Publications, MOSCOW
5. High Voltage Technology - LL Alston, Oxford University Press 1968.
6. Insulation Engineering- by Arora ,John Wiley & Sons
7. Insulating Materials-by Dekker,S.Chanda& Co
8. Dieletrics and waves-by vonhipple,John Wiley & Sons

I-I	**HVDC TRANSMISSION** **(Common to AEPS & HVE)**	**L / P / Credits** **4 / -- / 3**

Prerequisites: Knowledge on Power Electronics, Power Systems and High Voltage Engineering

Course Educational Objectives:

- To learn various schemes of HVDC transmission.
- To learn about the basic HVDC transmission equipment.
- To learn the control of HVDC systems.
- To be exposed to the interaction between HVAC and HVDC system.
- To be exposed to the various protection schemes of HVDC engineering.

Unit -1: Limitation of EHV AC Transmission, Advantages of HVDC Technical economical reliability aspects. HVDC Transmission: General considerations, Power Handling Capabilities of HVDC Lines, Basic Conversion principles, static converter configuration. Types of HVDC links-Apparatus and its purpose.

Unit-2: Static Power Converters: 6-pulse bridge circuit and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Comparison of the performance of diametrical connection with 6-pulse bridge circuit

Unit-3 : Control of HVDC Converters and systems : constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control. Factors responsible for generation of Harmonics voltage and current harmonics effect of variation of α and μ. Filters Harmonic elimination.

Unit-4 : Interaction between HV AC and DC systems – Voltage interaction, Harmonic instability problems and DC power modulation. Development of DC circuit Breakers, Multi-terminal DC links and systems; series, parallel and series parallel systems, their operation and control.

Unit -5 : Transient over voltages in HV DC systems : Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults. Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC line protection, circuit breakers. Over voltage protection of converters, surge arresters.

Course Outcomes:

After completion of this course the students will be able to:

- Understand the various schemes of HVDC transmission.
- Understand the basic HVDC transmission equipment.
- Understand the control of HVDC systems.
- Understand the interaction between HVAC and HVDC system.
- Understand the various protection schemes of HVDC engineering.

Reference Books:

1. S Kamakshaih and V Kamaraju:HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi – 1992.
3. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
4. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
5. Vijay K Sood: HVDC and FACTS controllers:Applications of static converters in power systems by, Kluwer Academic Press.

I-I

POWER SYSTEM OPERATION AND CONTROL
(Common to AEPS & HVE)

L / P / Credits
4 / -- / 3

Prerequisites: Knowledge on Power Generation Engineering, Power Transmission Engineering.

Course Educational Objectives:

- To study the unit commitment problem for economic load dispatch.
- To study the load frequency control of single area and two area systems with and without control.
- To study the effect of generation with limited energy supply.
- To study the effectiveness of interchange evaluation in interconnected power systems.

Unit-1: Unit commitment problem and optimal power flowsolution: Unitcommitment: Constraints in UCP,UC solutions. Methods-priority list method, introduction to Dynamic programming Approach.
Optimal power flow: OPF without inequality constraints, inequality constraints on control variables and dependent variables.

Unit-2: Single area Load Frequency Control: Necessity of keeping frequency constant. Definition of control area, single area control, Block diagram representation of an isolated Power System, Steady State analysis, Dynamic response-Uncontrolled case. Proportional plus Integral control of single area and its block diagram representation, steady state response, load frequency control and Economic dispatch control.

Unit-3: Two area Load Frequency Control : Load frequency control of 2-area system, uncontrolled case and controlled case, tie-line bias control. Optimal two-area LF control-steady state representation, performance Index and optimal parameter adjustment.

Unit-4: Generation with limited Energy supply : Take-or-pay fuel supply contract, composite generation production cost function. Solution by gradient search techniques, Hard limits and slack variables, Fuel scheduling by linear programming.

Unit-5 : Interchange Evaluation and Power Pools Economy Interchange, Economy interchange Evaluation, Interchange Evaluation with unit commitment, Multiple Interchange transactions, Other types of Interchange, power pools, transmission effects and issues.

Course Outcomes:
After completion of this course the students will be able to:

- Determine the unit commitment problem for economic load dispatch.
- Get the knowledge of load frequency control of single area and two area systems with and without control.
- Know the effect of generation with limited energy supply.
- Determine the interchange evaluation in interconnected power systems.

Reference Books:

1 Modern Power System Analysis - by I.J.Nagrath&D.P.Kothari, Tata McGraw-Hill Publishing Company ltd, 2nd edition.
2 Power system operation and control PSR Murthy B.S publication.
3 Power Generation, Operation and Control - by A.J.Wood and B.F.Wollenberg,Johnwiley& sons Inc. 1984.
4 Electrical Energy Systems Theory - by O.I.Elgerd, Tata McGraw-Hill Publishing Company Ltd, 2nd edition.
5 Reactive Power Control in Electric Systems - by TJE Miller, John Wiley & sons.

I-I **ARTIFICIAL INTELLIGENCE TECHNIQUES** **L / P / Credits**
(Common to AEPS & HVE) **4 / -- / 3**
(Elective-I)

Prerequisites: Basic knowledge on human biological systems, concept of optimization and electrical engineering.

Course Educational Objectives:

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm and its application in optimization.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in electrical engineering.

Unit – 1: Introduction to Neural Networks

Introduction, Humans and Computers, Biological Neural Networks, Historical development of neural network, Terminology and Topology, Biological and artificial neuron models, Learning laws-supervised, unsupervised and reinforced learning laws.

Unit- 2:Feed Forward Neural Networks

Introduction, Perceptron models: Discrete, continuous and multi-category, Training algorithms: Discrete and Continuous Perceptron Networks, Limitations and applications of the Perceptron model, Generalized delta learning rule, Feed forward recall and error back propagation training-Radial basis function algorithms, kohonen's self-organising maps -Hope field networks

Unit -3: Fuzzy Logic

Introduction to classical sets - properties, operations and relations; Fuzzy sets - properties, operations and relations, Uncertainty, cardinalities, membership and types of membership functions.Fuzzy Logic System Components-Fuzzification, Membership value assignment, development of rule base and decision making system, defuzzification to crisp sets, defuzzification methods.

Unit – 4: Genetic algorithms &Modelling-introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm

UNIT 5: Application of AI Techniques-load forecasting-load flow studies-economic load dispatch-load frequency control-reactive power control-speed control of dc and ac motors

Course Outcomes:

After completion of this course the students will be able to:

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and design fuzzy logic systems.
- Apply AI Techniques in electrical engineering.

Reference Books :

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by RajasekharanandPai – PHI Publication.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.

I-I	**ADVANCED DIGITAL SIGNAL PROCESSING** **(Common to AEPS & HVE)** **(Elective I)**	**L / P / Credits** **4 / -- / 3**

Prerequisites: Knowledge on signal processing and Z-transform.

Course Educational Objectives:

- To have knowledge on structures of different digital filters.
- To design digital filters with different techniques.
- To understand the implementation aspects of digital filters.
- To analyze the effect of finite word length in signal processing.
- To understand power spectrum estimation techniques in signal processing.

UNIT-1: Digital Filter Structure

Block diagram representation-Equivalent Structures-FIR and IIR digital filter Structures All pass Filters-tunable IIR Digital Filters-IIR tapped cascaded Lattice Structures-FIR cascaded Lattice structures-Parallel-Digital Sine-cosine generator-Computational complexity of digital filter structures.

UNIT-2: Digital filter design

Preliminary considerations-Bilinear transformation method of IIR filter design-design of Low pass high pass-Band pass, and Band stop- IIR digital filters-Spectral transformations of IIR filters, FIR filter design-based on Windowed Fourier series- design of FIR digital filters with least –mean- Square-error-constrained Least-square design of FIR digital filters

UNIT-3: DSP algorithm implementation

Computation of the discrete Fourier transform- Number representation-Arithmetic operations-handling of overflow-Tunable digital filters-function approximation.

UNIT-4 : Analysis of finite Word length effects

The Quantization process and errors- Quantization of fixed -point and floating -point Numbers-Analysis of coefficient Quantization effects - Analysis of Arithmetic Round-off errors, Dynamic range scaling-signal- to- noise ratio in Low -order IIR filters-Low-Sensitivity Digital filters-Reduction of Product round-off errors using error feedback-Limit cycles in IIR digital filters-Round-off errors in FFT Algorithms.

UNIT 5: Power Spectrum Estimation

Estimation of spectra from Finite Duration Observations signals – Non-parametric methods for power spectrum Estimation – parametric method for power spectrum Estimation, Estimation of spectral form-Finite duration observation of signals-Non-parametric methods for power spectrum estimation-Walsh methods-Blackman & torchy method.

Course Outcomes:

After completion of this course the students will be able to:

- Describe structure of digital filters.
- Design digital filters with different techniques.
- Understand the implementation aspects of signal processing algorithms.
- Know the effect of finite word length in signal processing.
- Analyze different power spectrum estimation techniques.

Reference Books:

1. Digital signal processing-sanjit K. Mitra-TMH second edition
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1st edition-9th reprint
3 Digital Signal Processing principles, algorithms and Applications – John G.Proakis -PHI – 3rd edition-2002
4. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2nd reprint-2001
5. Theory and Applications of Digital Signal Proceesing-LourensR. Rebinar&Bernold
6. Digital Filter Analysis and Design-Auntonian-TMH

I-I **SMART GRID TECHNOLOGIES** **L / P / Credits**
(Elective – I) **4/ -- / 3**

Perquisites: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

Course Educational Objectives:

- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

Unit 1

Introduction to Smart Grid: Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient &Self Healing Grid, Present development & International policies on Smart Grid. Case study of Smart Grid.

Unit 2

Smart Grid Technologies: Part 1: Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

Unit 3

Smart Grid Technologies: Part 2: Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

Unit 4

Microgrids and Distributed Energy Resources: Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuelcells, microturbines, Captive power plants, Integration of renewable energy sources.

Unit 5

Power Quality Management in Smart Grid: Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Information and Communication Technology for Smart Grid: Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).

Course Outcomes:

After completion of the course, students will be able to:

- Understand smart grids and analyse the smart grid policies and developments in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyse micro grids and distributed generation systems.
- Analyse the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

Text Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley publishers.
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response",CRC Press
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,"Smart Grid: Technology and Applications", Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell 19
5. Peter S. Fox Penner, "Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities", Island Press; 1 edition 8 Jun 2010
6. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active DistributionNetworks." Institution of Engineering and Technology, 30 Jun 2009
7. Stuart Borlase, "Smart Grids (Power Engineering)", CRC Press

Reference Books:

1. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability: 1", Artech House Publishers July 2011
2. James Northcote, Green, Robert G. Wilson "Control and Automation of Electric Power Distribution Systems (Power Engineering)", CRC Press
3. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert "Substation Automation (Power Electronics and Power Systems)", Springer
4. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Publication
5. Yang Xiao, "Communication and Networking in Smart Grids", CRC Press

I-I BREAKDOWN PHENOMENON IN ELECTRICAL INSULATION (Gases, Liquids, Solids and Vacuum) (ELECTIVE-I) **L / P / Credits 4 / -- / 3**

Prerequisites: Basic physics, conduction phenomena in dielectrics.

Course Educational Objectives:

- Understand the fundamental processes of conduction in gases.
- Ionization and breakdown phenomena in gases.
- Breakdown phenomena in liquid and solid dielectrics.
- Breakdown phenomena in vaccum.

Unit 1: Fundamentals of Electrical Breakdown Phenomena in Gases:

Review of gas laws-mean free path of a particle-velocity distribution of swarm of molecules-Expression for mean free path (λ)-Distribution of free paths-Bohr's model of an atom .calculation of radius of Bohr's orbit Energy of an electron-Ionization energy of an atom calculation of frequency of emitted radiation.

Unit 2: Ionization Its Gases:

Methods of ionization in gases-Ionization by collision-types of inelastic collisions – collision cross sections.

Behavior of charged particles in a gas in electric fields of low (E/P)-drift velocity –mobility conditions for low (E/P).

Electrical Breakdown in Uniform Fields:

Voltage-current relationship is gaseous gap (small gaps)-condition for high (E/P)-Townsend's first Ionization coefficient (α) - (α/p) is a function of (E/P)-Experimental determination of (α) – Penning effect

Unit 3:Self-sustained discharge:

β-process and its limitations cathode process –methods of liberating secondary electrons – Townsend's second ionization coefficient -γ -process . Condition for electric spark breakdown. Secondary emission by gas produced photons – Meta stables-Role of solid contaminants. Electron Attachment, electronegative gases (SF_6etc).

Measurement of 'γ'- Paschen's law –expression for Minimum Breakdown voltage and minimum (Pd_{min}) - limitations of Paschen's law.

Breakdown of long gaps: Streamer Mechanism- Explanation for positive streamer. Estimation of space charge fields (Es) - Anode directed streamer - comparison between Townsend and streamer mechanism. Breakdown in non-uniform fields –corona discharges - difference between DC and AC corona. Effect of polarity on break down of point-plane gaps.

Unit 4: Breakdown in Solids and Liquid Insulations:

Types of Breakdown: Intrinsic Breakdown – Electronic Breakdown – Streamer Breakdown – Electromechanical Breakdown –Thermal Breakdown -treeing and tracking. Electro – Chemical Breakdown – BD due to thermal discharges.

Breakdown in liquids dielectrics:
Pure and commercial liquids – Breakdown tests – Pre-breakdown currents and breakdown in pure liquids – breakdown in commercial liquids –Suspended particle theory, cavitations and bubble mechanism. Thermal breakdown – Stressed oil – Volume Theory.

Unit 5: Breakdown in Vacuum Insulation:
Pre-Breakdown currents – Steady currents –Micro discharges-Factors affecting the Breakdown . like electrode separation - electrode conditioning - electrode material –Surface condition surface contamination - electrode area and configurations –effect of electrode temperature – frequency of applied voltage – pressure - recovery strength of vacuum gap. Practical Exchange theory –electron beam Hypothesis – Clump mechanism- transition in breakdown mechanisms – criteria for B.D - effect of solids dielectrics in vacuum and liquids.

Course Outcomes:
After completion of this course the students will be able to:

- Understand the fundamental process of conduction in gases.
- Understand ionization and breakdown phenomena in gases.
- Understand breakdown phenomena in liquid and solid dielectrics.
- Understand breakdown phenomena in vaccum.

References Books:

1. Fundamentals of gaseous ionization and plasma electronics by EssamNassar,John Wiley, New York (1974).
2. High voltage & electrical insulation by RavindraArora , John willy and sons.
3. High voltage technology –L.L.Alston -Oxford Press (1968).
4. High voltage Engineering Fundamentals E. Kuffel, W. S. Zaengl,andJ. Kuffel oxford (2002).
5. High voltage Engineering, M.S.Naidu and V.Kamaraju (5th edition) McGraw Hill Publishing Co., New Delhi (2011).

I-I HIGH VOLTAGE POWER APPARATUS AND DIAGNOSTICS (Elective-II) **L / P / Credits 4 / -- / 3**

Prerequisites: To know about power transformers, Degree of polymerization, dissolved gas analysis, Fourier Transformer and frequency response analysis of transformers.

Course Educational Objectives:

- To study about components of power transformer, types of insulation material, overvoltage due to lightning impulse & faults.
- To study the measurement of resistivity and capacitance of transformer oil, method of measurement of tan delta and analysis to detect ageing.
- To study the concept of moisture in transformer oil and paper and partial discharges detection methods within transformer volume.
- To study the degree of polymerization and to determine tan delta and capacitance in transformer bushing.
- To Study the concept of Fourier Transformer with regard to configuration of winding, frequency response analysis of transformer winding..

Unit 1: Introduction to power transformer, important components of power transformer, winding configuration, various types of insulation material, cooling of winding. Reasons of failure of transformer, overvoltage due to switching operation, over-voltage due to lightning impulse, over voltage due to fault, high level of partial discharges, over fluxing.

Unit 2 : Tan delta, capacitance in transformer winding, method of measurement of tan delta and capacitance in transformer ,Tan delta ,resistivity and capacitance of transformer oil, bushing capacitance ,tan delta and resistivity, on-site measurement, analysis to detect ageing and likely failure

Unit 3: Moisture in transformer oil and paper, ageing effect of paper, insulation resistance, Method of measurement of polarization, polarization value, method of moisture reduction, winding resistance, Influence with regard to life of transformer. Partial Discharges in transformer, causes of partial discharges, concept of partial discharges, acoustic method of measurement of partial discharges, discharges in oil, discharges in paper, method of reduction of partial discharges, analysis and detection of partial discharge sites within transformer volume.

Unit 4 : Degree of polymerization (DP) of transformer paper, effect of DP on life of transformer, effect of transformer temperature on degree of polymerization, furfural content in oil insulation, inter – relationship between degree of polymerization and furfural content, reduction of degree of polymerization in transformer paper. Dissolved gas analysis in transformer oil, various gas product in transformer oil, tolerable level of gases in transformer onload , detection of important gases in transformer, causes of various gases, likely reason of gases with reference to high temperature and partial discharges.

Unit 5: Fourier Transform and frequency response analysis of transformer winding, concept of Fourier Transformer with regard to configuration of winding, comparison of frequency response

of LV , HV and tapping winding, concept of winding movement on the basis of frequency comparison, turn failure.

Course Outcomes:

After completion of this course the students will be able to

- learn power transformer, types of insulation material.
- the measurement of tan delta and capacitance of transformer oil.
- know the concept of moisture in transformer oil and paper and partial discharges.
- know degree of polymerization.
- know concept of Fourier Transformer and frequency response analysis of transformer winding.

Text Book:

1. Transformer, Bharat Heavy Electricals Limited (Bhopal), Second edition 2003,First Edition 1987 Tata Mc.Graw-hill Publishing Company Ltd. Mc.Graw –Hill officePage 1- 602

Reference book

1 Seminar on fault finding and life assessment of power transformers Proceedings 25-26 April2008 New Delhi, Organized by Central Board of Irrigation and Power, New Delhi in association with Omicron India.

2.Transformer Engineering, Blue mend boission, Wiley international publication.

I-I **COLLISION PHENOMENA IN PLASAMA SCIENCE (Elective-II)** **L / P / Credits 4 / -- / 3**

Prerequisites: Introduction to plasma physics and quantum physics
Course Educational Objectives: student will be exposed to

- Plasmas and their characterizations
- Charged particle motion in electromagnetic fields.
- Electron Avalanche mechanisms.

Unit 1 : 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 2 : Behavior of charged particles in a gas in electric fields of low E/P and high E/P, Definition and significance of mobility, Forces between ions and molecules, Diffusion under low fields, Electron drift velocity.

Unit 3 : What is high E/P?, Coefficient of ionization by electron collision, evaluation of $\propto$, electron avalanche, effect of the cathode, Ionization coefficient in alternating fields.

The Self-Sustaining Discharge Breakdown Mechanisms: Ionization by positive-ion collision, Cathode processes, space-charge field of an avalanche. Critical avalanche size,

Unit 4: Townsend mechanism and its limitations, Streamer formation. The transition between the breakdown mechanisms, The effect of electron attachment.

Partial Breakdown and Breakdown Under Alternating Fields: Electron current, positive-ion current, total current, characteristic time, effect of space charge, Anode coronas, Cathode coronas.

Unit 5: The 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.

Course Outcomes:

After completion of this course the students will be able to

- Understand the collision phenomena in different materials.
- Transition from Streamer to Townsend mechanisms of breakdown.
- Electric glow discharge and plasma glow discharge.

Reference Book:

1. Fundamentals of Gaseous Ionization And Plasma Electronics by Essam Nasser, John Willey & Sons, Printed in America, 1971.

I-I	ADVANCED EM FIELDS (Elective-II)	L / P / Credits 4 / -- / 3

Prerequisites: To know the elements of Electromagnetic and electro static field theory along with the behavior of conductors in an electric field.

Course Educational Objectives:

- To know the analytical calculations of field with space charges electric stress and equation of continuity.
- To know the electric field inside a dielectric material, energy density in a static electric field.
- To know the numerical methods for calculating electrical fields, statically dynamically induced e.m.f. calculations of transmission lines conductors to ground.

Unit – 1: Electrostatics:

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, div (D)=ρv – Laplace's and Poisson's equations – Solution of Laplace's equation in one variable

Unit – 2 :Electric fields-1

Introduction, Analytical calculation of space-charge-free fields, simple geometries, transmission conductors to ground, fields in multidielectric media, experimental analogs for space-space-charge-free fields, electrolytic tank, semi conducting paper analog, resistive-mesh analog.,

Unit – 3 Electric fields-2

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, Electric Stress Control, Electric Stress Optimization

Unit – 4 : Conductors & Dielectrics :

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

Unit – 5: Force in Magnetic fields &Time Varying Fields:

Magnetic force - Moving charges in a Magnetic field – Lorentz force equation — a differential current loop as a magnetic dipole ,Time varying fields – Faraday's laws of electromagnetic induction – Its integral and point forms ,Statically and Dynamically induced EMFs -Modification of Maxwell's equations for time varying fields – Displacement current

Course Outcomes:

After completion of this course the students will be able to:

- know about analysis of electrostatic fields and properties of potential gradients.
- knows about the dielectric boundary conditions and electric stress control and optimization and time varying fields.

Text Books:

1. "Engineering Electromagnetic" by William H. Hayt& John. A. Buck McGraw-Hill Companies, 7th Editon.2005.
2. "Electromagnetics" by J. D Kraus Mc.Graw-Hill Inc. 4th edition 1992.

Reference Books:

1. Field Theory ", Gangadhar, Khanna Publishers.
2. Elements of Electromagnetic field theory ", Sadiku, Oxford Publ.
3. "Electromagnetics" by J P Tewari.
4. "Introduction to E-Magnetics" by CR Paul and S.A. Nasar, McGraw-Hill Publications
5. "Introduction to Electro Dynamics" by D J Griffiths, Prentice-Hall of India Pvt.Ltd, 2nd
6. editon
7. "Electromagnetics" by Plonsy and Collin
8. "Engineering Electro magnetics" by Nathan Ida, Springer (India) Pvt. Ltd.2nd Edition.

I-I **HIGH VOLTAGE LABORATORY** **L / P / Credits**
-- / 4 / 2

Course Educational Objectives:

To understand the operation of high voltage generation and testing the various insulators.

Any 10 of the following experiments are to be conducted

List of Experiments:

1. Millivolt drop test and Tong tester calibration
2. Breakdown characteristics of sphere-sphere gap
3. Measurement of Leakage current and breakdown voltage of pin insulator
4. Breakdown test of transformer oil
5. Breakdown characteristics of rod-rod gap
6. Measurement of Leakage current and insulation resistance of polypropylene scale
7. Measurement of Leakage current and insulation resistance of polypropylene rope
8. Breakdown characteristics of plane-rod-gap
9. Measurement of leakage current and breakdown voltage of suspension insulator
10. Breakdown characteristics of point-sphere gap
11. Measurement of tan delta and dielectric constant
12. Power frequency testing of HV transformer
13. Power frequency testing of HV Bushing
14. Power frequency testing of HV Cable.

Course Outcomes:

After the Completion of lab will understand testing procedures of various insulators.

I-II	**HIGH VOLTAGE TESTING TECHNIQUES (Common to AEPS & HVE)**	**L / P / Credits 4/ -- / 3**

Prerequisites: Basics of high voltage engineering.

Course Educational Objectives:

- To understand Nondestructive testing methods.
- To understand Commercial and technical testing of different HV power applications.

Unit 1 : Non Destructive Testing Techniques : Measurement of DC Resistivity – Dielectric loss and dielectric constant of insulating materials – Schering bridge method – Transformer ratio arm bridge for high voltage and high current applications – null detectors.

Unit 2 : High Voltage Testing of Power Apparatus : Need for testing standards – Standards for porcelain/Glass insulators-Classification of porcelain/glass insulator tests – Tests for cap and pin porcelain/Glass insulators.

Unit 3 : High voltage AC testing methods-Power frequency tests-Over voltage tests on insulators, Isolators, Circuit Breakers and power cables. Artificial Contamination Tests : Contamination flashover phenomena-Contamination Severity-Artificial contamination tests-Laboratory Testing versus in-Service Performance-Case study.

Unit 4 : Impulse Testing : Impulse testing of transformers, insulators, Surge diverters, Bushings, cables, circuit breakers.

Unit 5 : Partial Discharge Measurement : PD equivalent model-PD currents-PD measuring circuits-Straight and balanced detectors-Location and estimation of PD in power apparatus-PD measurement by non electrical methods-Calibration of PD detectors. RIV Measurements : Radio Interference – RIV – Measurement of RI and RIV in laboratories and in field. Different test arrangements and their limitations.

Course Outcomes:

After completion of this course the students will be able to:

- Understand different testing procedures on electrical a) Insulating materials b) Insulation Systems. c) Power apparatus.
- Learn the different testing techniques adopted on electrical power apparatus.

Reference Books :

1. High Voltage Engineering – by E.KUFFEL and W.S.ZAENGL, Pergamon press, Oxford 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamaraju, Tata McGraw Hill Publishing Company Limited, New Delhi – 2001.
3. Discharge Detection in H.V. Equipment – by KREUGER, F.H. Haywood London – 1964.
4. Hyltencavallius. N. High voltage laboratory planning EnileHaefely&Co. Ltd. Based Switzerland 1988
5. Ryan H.M. and Whiskand: design and operation perspective of British UHV Lab IEE pre 133 H.V. Testing Techniques Halfly

I-II	EHVAC TRANSMISSION	L / P / Credits
		4 / -- / 3

Prerequisites: Transmission line parameters and properties, Corona etc.

Course Educational Objectives:

- To calculate the transmission line parameters.
- To calculate the field effects on EHV and UHV AC lines.
- To have knowledge of corona, RI and audible noise in EHV and UHV lines.
- To have knowledge of voltage control and compensation problems in EHV and UHV transmission systems.

Unit-1: E.H.V. A.C. Transmission , line trends and preliminary aspects ,standard transmission voltages – power handling capacities and line losses – mechanical aspects. Calculation of line resistance and inductance: resistance of conductors, temperature rise of conductor and current carrying capacity. Properties of bundled conductors and geometric mean radius of bundle, inductance of two conductor lines and multi conductor lines, Maxwell's coefficient matrix. Line capacitance calculation.capacitance of two conductor line, and capacitance of multi conductor lines, potential coefficients for bundled conductor lines, sequence inductances and capacitances and diagonalization.

Unit-2 : Calculation of electro static field of AC lines - Effect of high electrostatic field on biological organisms and human beings. Surface voltage Gradient on conductors, surface gradient on two conductor bundle and cosine law, maximum surface voltage gradient of bundle with more than 3 sub conductors, Mangolt formula.

Unit-3 : Corona : Corona in EHV lines – corona loss formulae – attenuation of traveling waves due to corona – Audio noise due to corona, its generation, characteristics and limits, measurement of audio noise.

Unit-4 : Power Frequency voltage control : Problems at power frequency, generalized constants, No load voltage conditions and charging currents, voltage control using synchronous condenser, cascade connection of components : Shunt and series compensation, sub synchronous resonance in series – capacitor compensated lines

Unit -5 : Static reactive compensating systems : Introduction, SVC schemes, Harmonics injected into network by TCR, design of filters for suppressing harmonics injected into the system.

Course Outcomes: After completion of the course, the student will be able to:

- Calculate the transmission line parameters.
- Calculate the field effects on EHV and UHV AC lines.
- Determine the corona, RI and audible noise in EHV and UHV lines.
- Analyze voltage control and compensation problems in EHV and UHV transmission systems.

Reference Books :

1. Extra High Voltage AC Transmission Engineering – Rakesh Das Begamudre, Wiley Eastern ltd., New Delhi – 1987.
2. EHV Transmission line reference book – Edison Electric Institute (GEC) 1986.

I-II SURGE PHENOMENON AND INSULATIONCO-ORDINATION

L / P / Credits
4 / -- / 3

Prerequisites: Basic concepts oftravelling wave techniques and their applications in electrical power systems, lightening and switching over voltages, insulation co-ordination in power systems.

Course Educational Objectives:

- To understand travelling wave phenomenon in transmission systems.
- To know different types of over voltages that originate in power systems.
- To know Insulation gradation for different electrical power apparatus and coordination in insulation systems.

Unit 1 : Traveling Waves : Transmission line equation, attenuation and distortion point-Typical cases.
Reflection of traveling waves: Behaviors of waves at a transaction point-Typical case. Travelling waves on multi conductor systems

Unit 2 : Successive Reflections : Reflection lattice, Effect of insulation capacitance. Standing waves and natural frequencies of transmission lines-Transient response of lines and systems with distributed parameters.

Unit 3 : Lightning Phenomena and over voltage in power systems. Mechanism of the lightning stroke – Mathematical model of the lightning stroke. Over voltages produced in power systems due to lightning – Over voltage due to faults in the system and switching surges. General principles of lightning protection – Tower – Footing resistance – Insulation withstand voltages and impulse flashover characteristics of protective gaps.

Unit 4 : Surge Voltage distribution in transformer windings initial and final distribution characteristics : Protection of windings against over voltages. protection of transmission lines, transformers and rotating machines against over voltages. Use of rod gaps and lightning arresters protective characteristics.Selection of the lightning arresters.

Unit 5 : Insulation coordination lightning surge and switching surge characteristics of insulation structures. Geo-metric gap factors test procedures, correlation between insulation for protective levels. Protective devices Znoarresters,vale type-etc, protective tubes

Course Outcomes: After completion of this course the students will be able to:

- Understand line concepts of travelling waves and their behavior in transmission systems.
- Understand lighting phenomena and over voltages in power systems.
- Understand the behavior of the transformer when surge voltages are induced in the windings.
- Understand the insulation coordination between different protecting and protective devices in the power system.

Reference Books :

1. Traveling waves of Transmission systems – by LV Bewley. Dover publications Inc., New York (1963).
2. Lewis, w.w., protection of transmission lines and systems against lightining, dover publications, Inc., New York (1965).
3. Diesendorf.W, Insulation Co-ordination ELBS in H.V. Electrical Power Systems , Butter worth publications, London, (1974).
4. Rakesh Das Begmudre,E.H.V. Transmission Engineering: Wielly Eastern Ltd., New Delhi, (1986).

I-II **ADVANCED POWER SYSTEM PROTECTION** **L / P / Credits**
(Common to AEPS & HVE) **4/ -- / 3**

Prerequisites: Concepts of Power Electronics, Electronic circuits, STLD and basics of Relays and protection.

Course Educational Objectives:

- To learn about classification and operation of static relays.
- To understand the basic principles and application of comparators.
- To learn about static version of different types of relays.
- To understand about numerical protection.

Unit 1 : Static Relays classification and Tools : Comparison of Static with Electromagnetic Relays, Basic classification, Level detectors and Amplitude and phase Comparators – Duality – Basic Tools – Schmitt Trigger Circuit, Multivibrators, Square wave Generation – Polarity detector – Zero crossing detector – Thyristor and UJT Triggering Circuits. Phase sequence Filters – Speed and reliability of static relays.

Unit 2 : Amplitude and Phase Comparators (2 Input) : Generalized equations for Amplitude and Phase comparison – Derivation of different characteristics of relays – Rectifier Bridge circulating and opposed voltage type amplitude comparators – Averaging & phase splitting type amplitude comparators – Principle of sampling comparators.

Phase Comparison : Block Spike and phase Splitting Techniques – Transistor Integrating type, phase comparison, Rectifier Bridge Type Comparison – Vector product devices.

Unit 3 : Static over current (OC) relays – Instantaneous, Definite time, Inverse time OC Relays, static distance relays, static directional relays, static differential relays, measurement of sequence impedances in distance relays, multi input comparators, elliptic & hyperbolic characteristics, switched distance schemes, Impedance characteristics during Faults and Power Swings,

Unit 4 : PILOT Relaying schemes: Wire pilot protection: circulating current scheme – balanced voltage scheme – translay scheme – half wave comparison scheme - carrier current protection: phase comparison type – carrier aided distance protection – operational comparison of transfer trip and blocking schemes – optical fibre channels.

Unit 5 : Microprocessor based relays andNumerical Protection: Introduction – over current relays – impedance relay – directional relay – reactance relay.
Numerical Protection: Introduction - numerical relay - numerical relaying algorithms - mann-morrison technique - Differential equation technique and discrete fourier transform technique - numerical over current protection - numerical distance protection.

Course Outcomes:

After completion of the course, the student will be able to:

- Know the classifications and applications of static relays.
- Understand the application of comparators.
- Understand the static version of different types of relays.
- Understand the numerical protection techniques.

Reference Books :

1. Power System Protection with Static Relays – by TSM Rao ,TMH.
2. Protective Relaying Vol-II Warrington, Springer .
3. Art & Science of Protective Relaying - C R Mason, Wiley.
4. Power System Stability KimbarkVol-II, Wiley.
5. Power system protection & switchgear by Badri Ram & D N viswakarma. TMH.
6. Electrical Power System Protection –C.Christopoulos and A.Wright- Springer
7. Protection & Switchgear –BhaveshBhalaja,R.PMaheshwari, NileshG.Chothani-Oxford publisher

I-II **L / P / Credits**
4 / -- / 3

PARTIAL DISCHARGES IN HV EQUIPMENT
(Elective-III)

Prerequisites: Knowledge in High Voltage Equipment.

Course Educational Objectives:

- To know about Partial Discharges, necessity of detection of partial discharge
- To know about effects of partial discharges on insulating systems.
- To know different detection methods used for partial discharges.

Unit 1 : Types of partial discharges and its occurrence and recurrence and magnitudes : Definition of Partial discharges, inception of internal discharges, Inception of corona discharges.

Unit 2 : Discharges by electrical treeing. Discharges at AC Voltages, corona discharges, Discharges at D.C. Voltages, discharges at impulse voltages.
Object of discharge detection, Quantities related to the magnitude of discharges, choice of PD as a measure for discharges.

Unit 3 : Electrical discharge detection & Detection circuits : Basic diagram, amplification of impulses, sensitivity, resolution, observation. Straight detection.
Balanced detection, calibrators, Interferences, choice between straight detection & balance detection, common mode rejection.

Unit 4 : Location of Partial discharges : Non-electric location, location by separation of electrodes, location with electrical probes. location by traveling waves, PD location in cables & switchgear by traveling waves. Evaluation of discharges: Recognition, mechanisms of deterioration, evaluation, specification.

Unit 5 : Detection in actual specimen : Detection in capacitors, cables, bushings. Transformers, machine insulation, Gas-insulated switchgear.

Course Outcomes:
After completion of the course, the student will be able to:

- Types of partial discharge that occurs in the insulation systems and in apparatus.
- Detection of discharges using different detection circuits.
- Location of partial discharge in electrical apparatus and systems.

Reference Book :

1. Partial Discharges in HV Equipment by F..Kruguer, Butterworths& Co., Publications Ltd., 1989.
2. Partial Discharges in Electrical Power Apparatus. by Dieter Konig, Y. NarayanaRao- VDE-Verlag publisher

I-II **GAS INSULATED SYSTEMS AND SUBSTATIONS** **L / P / Credits**
(Elective-III) **4 / -- / 3**

Prerequisites: Conduction and Breakdown in gases, and substation.

Course Educational Objectives:

- To Study and learn about SF_6 gas properties and application in electrical apparatus.
- To Study and learn about Details of SF_6 Substation.
- To Study and learn about Testing of G.I.S.

Unit 1

Introduction to GIS and Properties of SF6:

Characteristics of GIS, Introduction to SF_6, Physical Properties, Chemical Properties, Electrical Properties, Specifications of SF_6 Gas for GIS Applications, Handling of SF_6 Gas Before Use, Safe Handling of SF_6 Gas in Electrical Equipment, Equipment for Handling the SF_6 Gas, SF_6 and Environment.

Unit 2

Layout of GIS Stations:

Advantages of GIS Stations, Comparison With Air Insulated Substations, Economics of GIS,User Requirements for GIS,Main Features of a GIS,General Arrangement of a GIS,Planning and Installation,Components of a GIS station.

Unit 3

Design and Construction of GIS Stations:

Introduction,Ratings of GIS Components,DesignFeatures,Estimation of Different types of Electrical Stresses,Design Aspects of GIS Components,Insulation Design for GIS,Thermal Considerations in the Design of GIS,Effect of Very Fast Transient over voltages(VFTO)on the GIS Design,Insulation Coordination in GIS ,GIS Grounding Systems,Gas handling and Monitoring System Design.

Unit 4

Testing of GIS

Introduction, Various Tests on GIS,Design Approach for Manufacturing and Type Tests,Quality Assurance in Manufacturing,Shipping and Erection,On-Site Testing of GIS, Dielectric Tests, commonly used On-site Test Methods,Experience during On-Site Testing,Condition Monitoring and Diagnostic Methods.

Unit 5

GIS Diagnostics and Fast Transient Phenomena in GIS

Introduction,Characteristics of imperfections inInsulation,Insulation Diagnostic Methods,PDMeasurement,UHFMethod,Disconnector Switching in Relation to Very Fast Transients,Origin of VFTO, Propagation and Mechanism of VFTO,VFTO Characteristics,Effect of VFTO,Testing of GIS for VFTO.

Course Outcomes:

After completion of the course, the student will be able to:

- Know the Properties of SF_6
- Construction of G.I.S Substations
- Transient Phenomenon and testing of G.I.S

Text Book:

1. M.S.Naidu,"Gas Insulated Substations" I.K International publishing house Pvt.Ltd, New Delhi.

Reference Books:

1. O.Kindsen&K.V.Menon, " Future developments trend in GIS Technology" 3rd workshop & conference on EHV Technology, Indian Institute of Science, Bangalore, August 2-4, 1995.
2. V.N.Maller and M.S.Naidu "Advances in High Voltage Insulation & Arc Interruption in SF6 and Vaccum", Pergamon Press, Oxford, 1982.

I-II **L / P / Credits**
4 / -- / 3

PULSE POWER ENGINEERING
(Elective-III)

Prerequisites: Basic concepts of Pulse forming networks and energy storage devices

Course Educational Objectives:

- To know the static and dynamic breakdown strength of dielectric materials and various switches
- To know the energy storage device like Marx generator, inductive energy storage, rotor and homo polar generators, fly wheels.
- To know the design of pulse forming networks in transmission lines and power and voltage adding.

Unit1:**Static and Dynamic Breakdown Strength of dielectric Materials**

Introduction-Gases-static breakdown-pulsed breakdown-spark formation-liquids-basic electrical Process-steamer breakdown-practical considerations-solids-General observations-charge Transport, injection and Breakdown-statistical Interpretation of breakdown Strength Measurements

Unit2:Energy Storage

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

Unit3:**Switches**

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 4:Pulse forming networks:

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

Power and Voltage Adding: Adding of Power-Voltage Adding-voltage adding by transit-time Isolation- voltage adding by Inductive Isolation-Blumlein Generators-Cumulative Pulse Lines

Unit5:Examples of Pulsed-power Generators:

Single-pulse generators: KALIF-PBFA 2 and the Z-Machine- HERMES III

Repetitive Generators: RHEPP and Generators with opening switches

Course Outcomes:

After completion of the course, student will able to know

- Various energy storage devices, repetitive generators and cumulative pulse lines.
- Pulse forming networks and their applications.
- Pulse power generators.

Reference Books:

1.Pulsed Power Engineering by Professor Dr.HasjoachimBluhm.
2. Explosive Pulsed Power -L. L. Altgilbers, J. Baird, B. Freeman, C. S. Lynch, and S. I. Shkuratov -Imperial College Press.
3.Advances in Pulsed Power Technology, Vol. 1 & 2, Plenum Press.
4.Pulsed Power Systems: Principles and Applications-Dr.HasjoachimBluhm-Springer

I-II	FLEXIBLE AC TRANSMISSION SYSTEMS (Common to AEPS & HVE) (Elective- IV)	L / P / Credits 4 / -- / 3

Prerequisites: Concepts on Power Electronics and Power Systems

Course Educational Objectives:

- To study the performance improvements of transmission system with FACTS.
- To study the effect of static shunt compensation.
- To study the effect of static series compensation.
- To study the effect of UPFC.

Unit 1 : FACTS concepts, Transmission interconnections, power flow in an AC System, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

Unit 2 : Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters.

Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable VAr generation, variable impedance type static VAr generation, switching converter type VAr generation, hybrid VAr generation.

Unit 3: SVC and STATCOM: The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

Unit 4 : Static series compensators : Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), control schemes for GSC, TSSC and TCSC.

Unit 5 : Unified Power Flow Controller: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control, comparison of the UPFC to series compensators and phase angle regulators. Introduction to Inter line Power Flow Controller (IPFC)

Course Outcomes:

After completion of the course, the student will be able to:

- Know the performance improvement of transmission system with FACTS.
- Get the knowledge of effect of static shunt and series compensation.
- Know the effect of UPFC.
- Determine an appropriate FACTS device for different types of applications.

Reference Books:

1. "Understanding FACTS Devices" N.G.Hingorani and L.Guygi, IEEE Press. Indian Edition is available:--Standard Publications
2. Sang.Y.H and John.A.T, "Flexible AC Transmission systems" IEEE Press (2006).
3. HVDC & FACTS Controllers: applications of static converters in power systems- Vijay K.Sood- Springer publishers

I-II **L / P / Credits**
4 / -- / 3

POWER SYSTEM DEREGULATION

(Common to AEPS & HVE)

(Elective -IV)

Prerequisites: Knowledge onPower systems

Course Educational Objectives:

- To provide in-depth understanding of operation of deregulated electricity market systems.
- To examine typical issues in electricity markets and how these are handled world –wide in various markets.
- To enable students to analyze various types of electricity market operational and control issues using new mathematical models.

Unit 1

Need and conditions for deregulation. Introduction of Market structure, MarketArchitecture, Spot market, forward markets and settlements.Review ofConcepts marginal cost of generation, least-cost operation, incremental cost of generation. Power System Operation.

Unit 2

Electricity sector structures and Ownership /management, the forms of Ownership and management.Different structure model like Monopoly model, Purchasing agency model, wholesale competition model, Retail competition model.

Unit 3

Framework and methods for the analysis of Bilateral and pool markets, LMP based markets, auction models and price formation, price based unit commitment, country practices

Unit 4

Transmission network and market power. Power wheeling transactions and marginal costing, transmission costing.Congestion management methods- market splitting, counter-trading; Effect of congestion on LMPs- country practices

Unit 5

Ancillary Services and System Security in Deregulation. Classifications and definitions, AS management in various markets- country practices. Technical, economic, & regulatory issues involved in the deregulation of the power industry.

Corse Outcomes:

After completion of the course, the student will be able to:

- Understand of operation of deregulated electricity market systems
- Typical issues in electricity markets
- To analyze various types of electricity market operational and control issues using new mathematical models.

Reference Books:

1. Power System Economics: Designing markets for electricity - S. Stoft
2. Power generation, operation and control, -J. Wood and B. F. Wollenberg
3. Operation of restructured power systems - K. Bhattacharya, M.H.J. Bollen and J.E. Daalder
4. Market operations in electric power systems - M. Shahidehpour, H. Yaminand Z. Li
5. Fundamentals of power system economics - S. Kirschen and G. Strbac
6. Optimization principles: Practical Applications to the Operation and Markets of the Electric Power Industry - N. S. Rau
7. Competition and Choice in Electricity - Sally Hunt and Graham Shuttleworth

I-II **L / P / Credits**

REACTIVE POWER COMPENSATION & MANAGEMENT (Elective- IV)

4 / -- / 3

Prerequisites: Brief idea of power system analysis, electric traction systems and Arc furnaces

Course Educational Objectives:

- To know the basic objectives of reactive power compensation.
- To know the types of compensation and their behavior.
- To know the mathematical modeling of reactive power compensating devices.
- To know the reactive power compensation has to be done at distribution side.
- To know the role of reactive power compensation at electric traction systems and Arc furnaces.

Unit -1:Load Compensation

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 -2: Reactive power compensation in transmission system:

Steady state -Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples

Transient state - Characteristic time periods – passive shunt compensation – static compensations- series capacitor compensation –compensation using synchronous condensers – examples

Unit -3:Reactive power coordination:

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 -4: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

Unit-5: Reactive power management in electric traction systems and are furnaces:

Typical layout of traction systems – reactive power control requirements – distribution transformers- Electric arc furnaces – basic operations- furnaces transformer –filter requirements – remedial measures –power factor of an arc furnace

Course Outcomes: After completion of the course the student will be able to

- Learn various load compensations.
- Obtain the mathematical model of reactive power compensating devices.
- Get application of reactive power compensation in electrical traction & arc furnaces.

Reference Books:

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

I-II **SIMULATION LABORATORY** **L / P / Credits**
-- / 4 / 2

Course Educational Objectives: To understand the modeling of various aspects of Power System analysis and develop the MATLAB programming.

List of Experiments:

1. Formation of Y- Bus by Direct-Inspection Method.
2. Load Flow Solution Using Gauss Siedel Method
3. Load Flow Solution Using Newton Raphson Method
4. Load Flow Solution UsingFast Decoupled Method
5. Formation of Z-Bus by Z-bus building algorithm
6. Symmetrical Fault analysis using Z-bus
7. Unsymmetrical Fault analysis using Z-bus
8. Economic Load Dispatch with & without transmission losses
9. Transient Stability Analysis Using Point By Point Method
10. Load FrequencyControlof Single Area Control& Two Area Control system with and without controllers.

Course Outcomes: After the completion of the lab they will verify the theoretical concepts of various aspects of Power System analysis.