# JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

*(Established by an Act No.30 of 2008 of A.P. State Legislature)*

**Kukatpally, Hyderabad – 500 085, Andhra Pradesh (India)**

## M. TECH (HIGH VOLTAGE ENGINEERING/ POWER SYSTEMS WITH EMPHASIS ON H.V. ENGINEERING)

## (R13) COURSE STRUCTURE AND SYLLABUS

**I Year I Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | Generation and Measurement of High Voltages | 3 | 0 | 3 |
| | | Dielectric and Insulation Engineering | 3 | 0 | 3 |
| | | HVDC Transmission | 3 | 0 | 3 |
| | | Flexibility AC Transmission Systems (FACTS) | 3 | 0 | 3 |
| | Elective –I | Gas Insulated Systems (GIS)<br>AI Techniques<br>Voltage Stability | 3 | 0 | 3 |
| | Elective –II | Microcontrollers and Applications<br>Reactive Power Compensation and Management<br>Breakdown Phenomenon in Insulation | 3 | 0 | 3 |
| | Lab | High Voltage Laboratory | 0 | 3 | 2 |
| | | Seminar | - | - | 2 |
| | | **Total Credits** | 18 | 3 | 22 |

**I Year II Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | High Voltage Testing Technology | 3 | 0 | 3 |
| | | EHV AC Transmission | 3 | 0 | 3 |
| | | Surge Phenomena and Insulation Coordination | 3 | 0 | 3 |
| | | Advanced Power System Protection | 3 | 0 | 3 |
| | Elective –III | Partial Discharge in High Voltage Equipment<br>Programmable Logic Controllers and their Applications<br>Power System Transients | 3 | 0 | 3 |
| | Elective -IV | HV Transformers<br>Pulse Power Engineering<br>Advanced EM Fields | 3 | 0 | 3 |
| | Lab | Simulation Lab | 0 | 3 | 2 |
| | | Seminar | - | - | 2 |
| | | **Total Credits** | 18 | 3 | 22 |

**II Year I Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | Comprehensive Viva | - | - | 2 |
| | | Project Seminar | 0 | 3 | 2 |
| | | Project work | - | - | 18 |
| | | **Total Credits** | - | 3 | 22 |

**II Year II Semester**

| Code | Group | Subject | L | P | Credits |
|---|---|---|---|---|---|
| | | Project work and Seminar | - | - | 22 |
| | | **Total Credits** | - | - | 22 |

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## GENERATION AND MEASUREMENT OF HIGH VOLTAGES

### UNIT-I: 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-II: GENERATION OF HIGH VOLTAGES AND CURRENTS

**Direct Voltages:** AC to DC conversion methods, electrostatic generators – Cascaded Voltage Multipliers,
**Alternating Voltages:** Testing transformers – Resonant circuits and their applications.
**Impulse Voltages:** Impulse voltage specifications – Impulse generation 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-III: MEASUREMENT OF HIGH VOLTAGES

**Measurement of high DC Voltages:** Series resistance meters, voltage dividers and generating voltmeters.
**Measurement of high AC Voltages**: Series impedance meters, electrostatic voltmeters, potential transformers and CVTS – voltage dividers and their applications.

### UNIT-IV: MEASUREMENT OF PEAK VOLTAGE

Sphere gaps, uniform field gaps, rod gaps. Chubbs – Fortesuere methods. Passive and active rectifier circuits for voltage dividers.

### UNIT-V: MEASUREMENT OF IMPULSE VOLTAGES&CURRENTS

**Measurement of Impulse Voltage:** 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.

### REFERENCE BOOKS:

1. High Voltage engineering E Kuffel and W.S.Zaengl. Pergamon press, Canada Ltd., 1984.
2. High voltage engineering M.S.Naidu and V.Kamaraju, Tata Mcgraw Hill Book Co., New Delhi, 3nd edition 2004.
3. High voltage technology – LL Alston,Oxford University press, 1968
4. High voltage Measuring Techniques – A Schwab, MIT press Cambridge, USA 1972.
5. HV Engineering – Sabeer Ray

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## DIELECTRICAL AND INSULATION ENGINEERING

### UNIT-I: DIELECTRICS AND INSULATING MATERIAL

Review of Dielectric Phenomenon: Complex permittivity – Polarization – Relaxation and resonant models. Solid, Liquid and Gaseous insulating materials.

### UNIT-II: PROPERTIES OF DIELECTRICS AND INSULATING MATERIALS

Physical Thermal & Electrical properties-Classification of Insulating Materials,
**Solid Materials:** Organic Fiber materials Ceramics & Synthetic polymeric and their applications.
**Liquid Materials:** Insulating oils their properties and applications.
**Gaseous Materials:** Air and SF6 – applications in electrical apparatus.

### UNIT-III: BREAKDOWN PHENOMENON-I

Insulation and decay process-transition from self sustained discharges to breakdown. Townsend and streamer discharge paschen's law penning effect-Time lags-Surge breakdown voltage.

### UNIT-IV: BREAKDOWN PHENOMENON-II

Breakdown in non uniform fields-Vacuum insulation and vacuum breakdown. Breakdown Phenomenon in Liquid and Solid insulation: pure and commercial liquids-suspended particle and bubble theories-stressed oil volume theory.

### UNIT-V: BREAKDOWN PHENOMENON-III

Breakdown in solid insulation intrinsic breakdown-Treeing and tracking phenomenon-Thermal breakdown-Breakdown in composite dielectrics.

### REFERENCE BOOKS:

1. High Voltage Engineering – by E.Kuffel and W.S.Zaenal Pergamon press. Oxford 1984.
2. High Voltage Engineering – by M.S.Naidu and V.Kamarajuu, Tata Mc Graw Hill Book Co., New Delhi, 2nd edition, 1995.
3. Electrical Engineering Materials – B.Tareev, M.I.R. Publlications, Moscow.
4. APhysice of Dielectrics – B.Tareev, M.I.R. Publlications, Moscow.
5. High Voltage Technology – LL Alston, Oxford University Press 1968.

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## HVDC TRANSMISSION

### UNIT-I: INTRODUCTION

General consideration, Power Handling Capabilities of HVDC Lines Basic Conversion principles, static converter configuration.

### UNIT-II: STATIC POWER CONVERTERS

3-pulse, 6-pulse, and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter – special features of converter transformers. Harmonics in HVDC Systems, Harmonic elimination, AC and DC filters.

### UNIT-III: 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. Interaction between HV AC and DC systems – Voltage interaction Harmonic instability problems and DC power modulation.

### UNIT-IV: MTDC SYSTEMS & OVER VOLTAGES

Series parallel and series parallel systems their operation and control.
Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults.

### UNIT-V: CONVERTER FAULTS & PROTECTION

Converter faults, over current protection – valve group, and DC line protection over voltage protection of converters, surge arresters.

### REFERENCE BOOKS:

1. E.W. Kimbark: Direct current Transmission, Wiely Inter Science – New York.
2. J. Arillaga HVDC Transmission Peter Peregrinus ltd. London UK 1983
3. KR Padiyar : High Voltage Direct current Transmission Wiely Esatern Ltd New Delhi – 1992.
4. E. Uhlman : Power Transmission by Direct Current , Springer Verlag, Berlin Helberg. 1985.

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# FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

## UNIT-I: 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-II: VOLTAGE SOURCE CONVERTERS

Single phase three phase full wave bridge converters transformer connections for 12 pulse 24 and 48 pulse operation. Three level voltage source converter, pulse width modulation converter, basic concept of current source Converters, and comparison of current source converters with voltage source converters.

## UNIT-III: STATIC SHUNT COMPENSATION

Objectives of shunt compensation, mid-point voltage regulation voltage instability prevention, improvement of transient stability, Power oscillation damping, Methods of controllable VAR generation, variable impedance type static VAR generators switching converter type VAR generators hybrid VAR generators.

## UNIT-IV: 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 compensator control.

## UNIT-V: STATIC SERIES COMPENSATORS

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

## TEXT BOOKS:

1. “Understanding FACTS Devices” N.G. Hingorani and L. Guygi.
IEEE Press Publications 2000.

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## GAS INSULATED SYSTEMS (GIS)
## (Elective–I)

### UNIT–I: INTRODUCTION TO GIS AND PROPERTIES OF $SF_6$

Characteristics of GIS- Introduction to $SF_6$ - Physical properties-Chemical properties - Electrical properties-Specification of $SF_6$ gas for GIS application - 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–II: LAYOUT OF GIS STATIONS

Advancement of GIS station - Comparison with Air Insulated Substation - Economics of GIS - User Requirements for GIS - Main Features for GIS - Planning and Installation components of a GIS station.

### UNIT–III: DESIGN AND CONSTRUCTION OF GIS STATION

Introduction - Rating of GIS components - Design Features - Estimation of different types of Electrical Stresses -Design Aspects of GIS components - Insulation Design for 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 systems - Gas handling and Monitoring System Design.

### UNIT-IV: FAST TRANSIENT PHENOMENA IN GIS

Introduction- Disconnector Switching in Relation to Very fast Transients-Origin of VFTO-Propagation and Mechanism of VFTO-VFTO Characteristics- Effects of VFTO-Testing of GIS for VFTO.

### UNIT–V: SPECIAL PROBLEMS IN GIS AND GIS DIAGNOSTICS

Introduction - particles their effects and their control- Insulating Spacers and their Reliability - $SF_6$ Gas Decomposition - Characteristics of imperfections in insulation - Insulation Diagnostic methods - PD Measurement and UHF Method.

### TEXT BOOK:

1. M. S. Naidu," Gas Insulated Substations"- IK International Publishing House.

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## AI TECHNIQUES
## (Elective–I)

### UNIT – I: ARTIFICIAL NEURAL NETWORKS

Introduction-Models of Neural Network - Architectures – Knowledge representation – Artificial Intelligence and Neural networks–Learning process – Error correction learning – Hebbian learning –Competitive learning –Boltzmann learning –Supervised learning – Unsupervised learning – Reinforcement learning- learning tasks.

### UNIT- II: ANN PARADIGMS

Multi – layer perceptron using Back propagation Algorithm-Self – organizing Map – Radial Basis Function Network – Functional link, network – Hopfield Network.

### UNIT – III: FUZZY LOGIC

Introduction – Fuzzy versus crisp – Fuzzy sets - Membership function – Basic Fuzzy set operations – Properties of Fuzzy sets – Fuzzy cartesion Product –Operations on Fuzzy relations – Fuzzy logic – Fuzzy Quantifiers-Fuzzy Inference-Fuzzy Rule based system-Defuzzification methods.

### UNIT – IV: GENETIC ALGORITHMS

Introduction-Encoding –Fitness Function-Reproduction operators-Genetic Modeling –Genetic operators-Crossover-Single – site crossover-Two point crossover –Multi point crossover-Uniform crossover – Matrix crossover-Crossover Rate-Inversion & Deletion –Mutation operator –Mutation –Mutation Rate-Bit-wise operators-Generational cycle-convergence of Genetic Algorithm.

### UNIT–V: APPLICATIONS OF AI TECHNIQUES

Load forecasting – Load flow studies – Economic load dispatch – Load frequency control – Single area system and two area system – Small Signal Stability (Dynamic stability) Reactive power control – speed control of DC and AC Motors.

### TEXT BOOK:

1. S.Rajasekaran and G.A.V.Pai, “Neural Networks, Fuzzy Logic & Genetic Algorithms”- PHI, New Delhi, 2003.

### REFERENCE BOOKS:

1. P.D.Wasserman,Van Nostrand Reinhold,”Neural Computing Theory & Practice”- New York,1989.
2. Bart Kosko,”Neural Network & Fuzzy System” Prentice Hall, 1992.
3. G.J.Klir and T.A.Folger,”Fuzzy sets,Uncertainty and Information”-PHI, Pvt.Ltd,1994.
4. D.E.Goldberg,” Genetic Algorithms”- Addison Wesley 1999.

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## VOLTAGE STABILITY
## (Elective – I)

**UNIT–I: INTRODUCTION TO VOLTAGE STABILITY**

Definitions: Voltage Stability, Voltage Collapse, Voltage Security; Physical relation indicating dependency of voltage on reactive power flow; Factors affecting Voltage collapse and instability; Previous cases of voltage collapse incidences.

**UNIT–II: GRAPHICAL ANALYSIS OF VOLTAGE STABILITY**

Comparison of Voltage and angular stability of the system; Graphical Methods describing voltage collapse phenomenon: P-V and Q-V curves; detailed description of voltage collapse phenomenon with the help of Q-V curves.

**UNIT–III: ANALYSIS OF VOLTAGE STABILITY**

Analysis of voltage stability on SMLB system: Analytical treatment and analysis.

**Voltage Stability Indices:**

Voltage collapse proximity indicator; Determinant of Jacobin as proximity indicators; Voltage stability margin.

**UNIT–IV: POWER SYSTEM LOADS**

Loads that influences voltage stability: Discharge lights, Induction Motor, Air-conditioning, heat pumps, electronic power supplies, OH lines and cables.

**Reactive Power Compensation:**

Generation and Absorption of reactive power; Series and Shunt compensation; Synchronous condensers, SVC s; OLTC s; Booster Transformers.

**UNIT–V: VOLTAGE STABILITY MARGIN**

Stability Margin: Compensated and un-compensated systems.

**Voltage Security**

Definition; Voltage security; Methods to improve voltage stability and its practical aspects.

**TEXT BOOKS**:

1. "Performance, operation and control of EHV power transmission system"- A.CHAKRABARTHY, D.P.KOTARI and A.K.MUKOPADYAY, A.H.Wheeler Publishing, I Edition, 1995.

2. "Power System Dynamics: Stability and Control" – K.R.PADIYAR, II Edition, B.S.Publications.

**REFERENCE:**

1. "Power System Voltage Stability"- C.W.TAYLOR, Mc Graw Hill, 1994.

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## MICROCONTROLLERS AND ITS APPLICATIONS
## (Elective-II)

**UNIT-I: OVERVIEW OF ARCHITECTURE & MICROCONTROLLER RESOURCES**
Architecture of a microcontroller – Microcontroller resources – Resources in advanced and next generation microcontrollers – 8051 microcontroller – Internal and External memories – Counters and Timers – Synchronous serial-cum asynchronous serial communication - Interrupts.

**UNIT-II: 8051- MICROCONTROLLERS INSTRUCTION SET**
Basic assembly language programming – Data transfer instructions – Data and Bit-manipulation instructions – Arithmetic instructions – Instructions for Logical operations on the test among the Registers, Internal RAM, and SFRs – Program flow control instructions – Interrupt control flow.

**UNIT-III: REAL TIME CONTROL**
**INTERRUPTS:** Interrupt handling structure of an MCU – Interrupt Latency and Interrupt deadline – Multiple sources of the interrupts – Non-maskable interrupt sources – Enabling or disabling of the sources – Polling to determine the interrupt source and assignment of the priorities among them – Interrupt structure in Intel 8051.
**TIMERS:** Programmable Timers in the MCU's – Free running counter and real time control – Interrupt interval and density constraints.

**UNIT-IV: SYSTEMS DESIGN**
**DIGITAL AND ANALOG INTERFACING METHODS:**
Switch, Keypad and Keyboard interfacings – LED and Array of LEDs – Keyboard-cum-Display controller (8279) – Alphanumeric Devices – Display Systems and its interfaces – Printer interfaces – Programmable instruments interface using IEEE 488 Bus – Interfacing with the Flash Memory – Interfaces – Interfacing to High Power Devices – Analog input interfacing – Analog output interfacing – Optical motor shaft encoders – Industrial control – Industrial process control system – Prototype MCU based Measuring instruments – Robotics and Embedded control – Digital Signal Processing and digital filters.

**UNIT-V: REAL TIME OPERATING SYSTEM FOR MICROCONTROLLERS:**
Real Time operating system – RTOS of Keil (RTX51) – Use of RTOS in Design – Software development tools for Microcontrollers.
**16-BIT MICROCONTROLLERS:** Hardware – Memory map in Intel 80196 family MCU system – IO ports – Programmable Timers and High-speed outputs and input captures – Interrupts – instructions.
ARM 32 Bit MCUs: Introduction to 16/32 Bit processors – ARM architecture and organization – ARM / Thumb programming model – ARM / Thumb instruction set – Development tools.

**TEXT BOOKS:**

1. Raj Kamal," Microcontrollers Architecture, Programming, Interfacing and System Design"– Pearson Education, 2005.
2. Mazidi and Mazidi, "The 8051 Microcontroller and Embedded Systems" PHI, 2000.

**REFERENCE BOOKS:**
1. A.V. Deshmuk, "Microcontrollers (Theory & Applications)" – WTMH, 2005.
2. John B. Peatman, "Design with PIC Microcontrollers" – Pearson Education, 2005.

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## REACTIVE POWER COMPENSATION AND MANAGEMENT
## (Elective-II)

### UNIT-I: 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-II: 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
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
Load patterns – basic methods load shaping – power tariffs- KVAR based tariffs penalties for voltage flickers and Harmonic voltage levels.

**Distribution side Reactive power Management**:
System losses –loss reduction methods – examples – Reactive power planning – objectives – Economics Planning capacitor placement – retrofitting of capacitor banks.

### UNIT-V: 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.

**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.

### REFERENCE BOOKS:

1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982 (Units I to IV)
2. Reactive power Management by D.M.Tagare,Tata McGraw Hill,2004.(Units V to VIII)

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## BREAKDOWN PHENOMENON IN INSULATION
## (Elective-II)

**UNIT-I:**
**Introduction:** Electric stress and Electric strength, Breakdown mechanisms, Estimation and control of electric stress, Field sketching, high voltage measurements.

**UNIT-II:**
**Mechanisms Of Spark Breakdown In Gases:** Basic process in gas breakdown-Primary process-secondary process, Mechanisms of breakdown-Townsend Mechanism, breakdown in electronegative gases, Time lags of spark breakdown,
**Breakdown Characteristics In Gases:** Phenomenon in uniform fields, Phenomenon in non uniform fields, Surface flashover, dielectric recovery.

**UNIT-III:**
**Electrical Properties of High Vacuum:** Pre-breakdown conduction, Factors affecting the breakdown voltage, Breakdown hypotheses, Vacuum breakdown criterion, Flashover across solid insulators.
**The Electrical Conduction and Strength of Pure Liquids:** pure liquids, purification, test cells, natural conduction, induced conduction, process of conduction, breakdown phenomenon and electric strength of liquids, breakdown process.

**UNIT-IV:**
**Breakdown of Commercial Liquid and Liquid-Solid Dielectrics:** breakdown due to gaseous inclusions, breakdown due to liquid globules, breakdown due to solid particles, deterioration due to internal discharges, electrochemical deterioration.
**Intrinsic and Related Forms of Breakdown in Solids:** definition of intrinsic strength, theories of intrinsic strength, its measurements, comparison of theory with experiment, current problems in measurement of intrinsic strength.

**UNIT-V:**
**Thermal Breakdown Chemical and Electro Chemical Deterioration:** thermal breakdown, chemical deterioration-oxidation, chemical stability, hydrolysis, leaching of chemically active substances, incompatibility of materials, electrochemical deterioration-nature, electrochemical effects in insulation with and without moisture.

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## HIGH VOLTAGE LABORATORY

1. Determination of Breakdown strength of oil by Variable Distance Electrodes.
2. Milli Volt Drop Test (Calibration of Tong-tester).
3. Breakdown characteristics of Sphere air gap.
4. Breakdown characteristics of Plane Rod gap.
5. Breakdown Voltage of pin Insulator & Measurement of Leakage Current.
6. Measurement of Leakage current & Breakdown voltage of Suspension Insulators.
7. Voltage Distribution of String Insulators.
8. Measurement of Leakage current & Insulation resistance of Poly propylene Rope.
9. Measurement of Leakage current & Insulation resistance of Poly propylene Scale.
10. Fault analysis of 3-phase Alternator.

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## HIGH VOLTAGE TESTING TECHNOLOGY

### UNIT-I: NON DESTRUCTIVE TESTING TECHNIQUES

Measurement of DC Resistivity – Dielectric loss and dielectric constant of insulating materials – Schering bridge method – Transformer ration arm bridge for high voltage and high current applications – null detectors

### UNIT-II: HIGH VOLTAGE TESTING OF POWER APPARATUS

Need for testing standards – Standards for porcelain / Glass insulator – Classification of porcelain / glass insulator tests- Tests for cap and pin porcelain/ Glass insulators. High voltage AC testing methods, power frequency tests- Over voltage tests on insulators, Isolators, Circuit Breakers and power cables.

### UNIT-III: ARTIFICIAL CONTAMINATION TESTS

Contamination flashover phenomena – Contamination Severity- Artificial contamination tests- Laboratory Testing versus in-Service Performance –Case study.
Impulse Testing: Impulse testing of transformers – Surge diverters –and other apparatus.

### UNIT-IV: PARTIAL DISCHARGE MEASUREMENT

PD equivalent model-PD currents-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.

### UNIT-V: INSULATORS FAIL

Handling –Vandalism –Quality control – Application problems Detecting defective Non Ceramic insulators. Making Insulators work in contaminated environments: Cleaning Modification of Insulator design – Mobile protective coatings-Solid water Repellent coating –line voltage reduction.

### REFERENCES:

1. High Voltage Engineering – by E. KUFFEL and W.S. ZAEGNL 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. Equivpment – by KREUGER F.H. Haywood Londor- 1964.
4. Outdoor Insulators- by Gorur & Cherney.

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## EHV AC TRANSMISSION

**UNIT-I:**
E.H.V.A.C. Transmission line trends and preliminary aspect standard transmission voltages – Estimation at line and ground parameters-Bundle conductor systems-Inductance and Capacitance of E.H.V. lines – positive, negative and zero sequence impedance – Line Parameters for Modes of Propagation.

**UNIT-II:**
Electrostatic field and voltage gradients – calculations of electrostatic field of AC lines – effect of high electrostatic field on biological organisms and human beings - surface voltage gradients and maximum gradients of actual transmission lines – voltage gradients on sub conductor.

**UNIT-III**:
Electrostatic induction in unenergized lines – measurement of field and voltage gradients for three phase single and double circuit lines – un energized lines. Power Frequency Voltage control and over-voltages in EHV lines: No load voltage – charging currents at power frequency-voltage control – shunt and series compensation – static VAR compensation.

**UNIT-IV**:
Corona in E.H.V. lines – Corona loss formulae- attention of traveling waves due to Corona – Audio noise due to Corona, its generation, characteristic and limits. Measurements of audio noise radio interference due to Corona - properties of radio noise – frequency spectrum of RI fields – Measurements of RI and RIV.

**UNIT-V:**
Design of EHV lines based on steady state and transient limits - EHV cables and their characteristics.

**REFERENCE BOOKS:**

1. Rokosh Das Begamudre,"Extra High Voltage AC Transmission Engineering"– Wiley Eastern LTD., NEW DELHI – 1987.
2. Edison,"EHV Transmission line"- Electric Institution (GEC 1968).

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## SURGE PHENOMENA AND INSULATION COORDINATION

**UNIT-I:**
**Traveling Waves:** Transmission line equation, attenuation, distortion, types of traveling waves, Reflection of traveling waves at a transition point, typical cases.
**Successive Reflections:** Reflection lattice, line with different terminations, line-cable connection, line-cable-transformer connection.

**UNIT-II:**
**Lightning:** Mechanism of the lightning stroke, Mathematical model of lightning stroke. Over voltage due to lightning. Power frequency over voltages, over voltages due to faults. Switching over voltages, switching over voltage reduction techniques.

**UNIT-III:**
High voltage AC circuit breakers : Opposing forces during closing and opening operation, inter locks, indication and auxiliary switches, CB time, auto re-closure, transient recovery voltage, single frequency transient, double frequency transient, rate of rise of TRV, resistance switching, damping of TRV, opening resistors.

**UNIT-IV:**
Protection of power system against over voltages : General principles of lighting protection, ground wires, surge arresters, counter poises, tower footing resistances, protection of rotating machines against surges.

**UNIT-V:**
**Insulation characteristics of long air gaps:** Types of electrode geometries, breakdown characteristics of long air gaps, breakdown models of long gaps with non uniform fields, CFO and withstand voltages of long air gaps.
**Insulation Coordination:** Protective characteristics of rod gaps, surge arrestors, insulation withstand voltage characteristics, correlation between insulation and protective levels, and illustration of insulation coordination in an EHV substation.

**REFERENCE BOOKS:**

1. Traveling waves of Transmission systems – by LV Bewley.
2. Insulation Co-ordination ELBS in H.V. Electrical Power Systems by W.Diesendorf, Butter worth publications, London, 1974.
3. E.H.V. Transmission Engineering: Rakosh Das Begamudre, Wiley Eastern Ltd., New Delhi, 1986.

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## ADVANCED POWER SYSTEM PROTECTION

**UNIT-I: STATIC RELAYS**
Advantages of static relays-Basic construction of static relays-Level detectors-Replica impedance –Mixing circuits-General equation for two input phase and amplitude comparators-Duality between amplitude and phase comparators.
**AMPLITUDE COMPARATORS**: Circulating current type and opposed voltage type- rectifier bridge comparators, Direct and Instantaneous comparators.

**UNIT-II: PHASE COMPARATORS**
Coincidence circuit type- block spike phase comparator, techniques to measure the period of coincidence-Integrating type-Rectifier and Vector product type- Phase comparators.
**STATIC OVER CURRENT RELAYS:** Instantaneous over-current relay-Time over-current relays-basic principles –definite time and Inverse definite time over-current relays.

**UNIT-III: STATIC DIFFERENTIAL RELAYS**
Analysis of Static Differential Relays –Static Relay schemes –Duo bias transformer differential protection –Harmonic restraint relay.
**STATIC DISTANCE RELAYS:** Static impedance-reactance–MHO and angle impedance relay-sampling comparator –realization of reactance and MHO relay using sampling comparator.

**UNIT-IV: MULTI-INPUT COMPARATORS**
Conic section characteristics-Three input amplitude comparator –Hybrid comparator-switched distance schemes –Poly phase distance schemes- phase fault scheme –three phase scheme –combined and ground fault scheme.
**POWER SWINGS:** Effect of power swings on the performance of distance relays –Power swing analysis-Principle of out of step tripping and blocking relays-effect of line and length and source impedance on distance relays.

**UNIT-V: MICROPROCESSOR BASED PROTECTIVE RELAYS**
(Block diagram and flowchart approach only)-Over current relays–impedance relays-directional relay-reactance relay .Generalized mathematical expressions for distance relays-measurement of resistance and reactance –MHO and offset MHO relays-Realization of MHO characteristics-Realization of offset MHO characteristics -Basic principle of Digital computer relaying.

**TEXT BOOK:**

1. Badri Ram and D.N.Vishwakarma, “Power system protection and Switch gear “, TMH publication New Delhi 1995.

**REFERENCE:**

1. T.S.Madhava Rao , “Static relays”, TMH publication, second edition 1989.

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## PARTIAL DISCHARGES IN HIGH VOLTAGE EQUIPMENT
## (Elective-III)

**UNIT-I**:
Types of partial discharges and its occurrence and recurrence and magnitudes**:** Definition of partial discharges, inception of internal discharges, inception of corona discharges.

**UNIT-II:**
Discharges by electrical treeing. Discharges at AC Voltages corona 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-III:**
Electrical discharge detection & Detection circuits: Basic diagram, amplification of impulse, sensitivity, resolution, observation, Straight detection. Balanced detection, calibrators, Interferences, choice between straight detection & balance detection, common mode rejection.

**UNIT-IV:**
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-V:**
Detection in actual specimen: Detection in capacitors, cables, bushings. Transformers, machine insulation, Gas – insulated switchgear.

**REFERENCE:**

1 Partial Discharge in HV Equipment by F. Kruguer, Butterworths & Co,
Publications Ltd 1989

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## PROGRAMMABLE LOGIC CONTROLLERS AND THEIR APPLICATIONS
## (Elective–III)

**UNIT-I:**
PLC Basics PLC system, I/O modules and interfacing CPU processor programming equipment programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

**UNIT-II:**
PLC Programming input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill-press operation.
Digital logic gates programming in the Boolean algebra system, conversion examples Ladder diagrams for process control Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

**UNIT-III:**
PLC Registers: Characteristics of Registers module addressing holding registers input registers, output registers. PLC Functions Timer functions and industrial applications counters counter function industrial applications, Architecture functions, Number comparison functions, number conversion functions.

**UNIT-IV:**
Data handling functions: SKIP, Master control Relay Jump Move FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axes and three axis Robots with PLC, Matrix functions.

**UNIT-V:**
Analog PLC operation: Analog modules and systems Analog signal processing multi bit data processing , analog output application examples, PID principles position indicator with PID control, PID modules, PID tuning, PID functions

**REFERENCE BOOKS:**

1. Programmable Logic Controllers – Principle and Applications by John W Webb and Ronald A Reiss Fifth edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR Hackworth and F.D Hackworth – Jr- Pearson, 2004.

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## POWER SYSTEM TRANSIENTS
## (Elective-III)

**UNIT-I:**
**Basic Concepts and Simple Switching Transients:** Switching an LR, LC, RLC circuits
**Transients Analysis of Three-Phase power Systems:** Symmetrical components in Three-phase Systems, Sequence Components for Unbalanced Network Impedances, the Sequence Networks, analysis of Unsymmetrical Three-Phase Faults-single line-to-Ground Fault, Three phase-to-ground faults.

**UNIT-II:**
**Travelling Waves:** Velocity of Travelling waves and Characteristic Impedance, Energy Contents of Travelling Waves, Attenuation and Distortion of Electromagnetic Waves, telegraph equations-lossless line, distortion less line, Reflection and Refraction of Travelling Waves, Reflection of Travelling Waves against Transformer-and-Generator-windings, the Origin Transient Recovery voltages, the lattice diagram.

**UNIT-III:**
**Circuit Breakers:** Switching arc, Oil Circuit Breakers, Air-Blast, SF6 Circuit Breakers, Vacuum Circuit Breakers, Modelling of the Switching Arc, Arc-Circuit Interaction.
**Switching Transients:** Interrupting Capacitive currents, Capacitive Inrush currents, Interrupting Small Inductive Currents, Transformer Inrush currents, Short Line Fault.

**UNIT-IV:**
**Power System Transient Recovery Voltages:** Characteristics of the Transient Voltage- Short-circuit test duties based on IEC 60056 (1987),ANSI/IEEE Standards, the Harmonization between IEC and ANSI/IEEE Standards with respect to Short-circuit Test duties, Transient recovery voltage for Different types of faults.

**UNIT-V:**
**Lightning –Induced Transients:** Mechanism of Lightning, Wave shape of the lightning current, direct lighting Stroke to transmission line towers, direct lightening stroke to a line.
**Numerical simulation of electrical transients:** The Electromagnetic Transient Program, The MNA Program, The X- Trans Program.

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## HIGH VOLTAGE TRANSFORMERS
## (Elective-IV)

**UNIT–I: WORKING PRINCIPLE OF A TRANSFORMER**
Brief idea about a transformer and how it operates in the distribution system. The working principle in respect of induced EMF, Transformer core and winding. End turns, Losses. Future requirement of transformers with the growth of the power scenario in India.

**UNIT-II: REQUIREMENTS OF TRANSFORMER**
**SPECIFICATIONS FORM END – USERS**
The basic information that buyers should pass on to the manufacturer while placing an order. Preparing specifications in respect of mandatory, Supplementary and additional requirements.

**UNIT-III: BASIC MATERIALS OF TRANSFORMS**
The processing of three basic new materials, viz. CRGO steel, winding wires and strips and transformer oil, raw material processors.

**UNIT–IV: THE BASIC CONCEPT OF DESIGN**
Design concepts, a commercial design, the design approach in respect of core and winding. The procedure of handling computer aided design, the design inputs and outputs, and operation. Two standard designs of 250 kVA and 400 kVA. 11/0.433 kV.

**UNIT–V: DRY – TYPE DISTRIBUTION TRANSFORMERS**
Basic constructional details and superiority of resign impregnated dry type transformers have been compared with oil filled and resin cast transformers. VPI plant requirements, application of dry type transformers.

**TEXT BOOKS:**
**1.** Design of Transformers, Indirajit Dasgupta, Tata Mc Graw Hill.

**REFERENCES:**
1. Transformers, BHEL, Tata Mc.Graw Hill Publishers.

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## PULSE POWER ENGINEERING
## (Elective-IV)

### UNIT-I: 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.

### UNIT-II: 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.

**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-III: 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.

### UNIT-IV: PULSE TRANSMISSION AND TRANSFORMATION

Self magnetic insulation in vacuum lines-vacuum break down in metallic surfaces-qualitative description of self magnetic insulation-quantitative description of self magnitude insulation-pulse Transformers-High Voltage Power supplies-Capacitor-Charging Techniques-Cascade Circuits-Transformation Lines.

### UNIT-V: 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.

**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.

### TEXT BOOK:

1. Pulsed Power Engineering by Professor Dr.Hasjoachim Bluhm.

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## ADVANCED EM FIELDS
## (Elective-IV)

### UNIT–I: 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 )=$\rho$v – Laplace's and Poisson's equations – Solution of Laplace's equation in one variable.

### UNIT–II: ELECTRIC FIELDS-I
Introduction, Analytical calculation of space-charge-free fields, simple geometries, transmission conductors to ground, fields in multi-dielectric media, experimental analogs for space-space-charge-free fields, electrolytic tank, semi conducting paper analog, resistive-mesh analog. 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, monte-cario technique.

### UNIT–III: ELECTRIC FIELDS-II
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–IV: CONDUCTORS, DIELECTRICS, DIPOLE AND CAPACITANCE
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 Electric dipole – Dipole moment – potential and EFI due to an electric dipole – Torque on an Electric dipole in an electric field – Capacitance – Capacitance of parallel plate and spherical capacitors. continuity.

### UNIT–V: MAGNETO STATICS TIME VARYING FIELDS
Biot-Savart's law – Magnetic field intensity (MFI), magnetic flux density and MFI, Ampere's circuital law and its applications Point form of Ampere's circuital law. Scalar Magnetic potential and its limitations – vector magnetic potential and its properties, vector Poisson's equations. Energy stored and density in a magnetic field. 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.

### TEXT BOOKS:
1. "Engineering Electromagnetics" by William H. Hayt & John. A. Buck Mc. Graw-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, Mc-Graw Hill Publications
5. "Introduction to Electro Dynamics" by D J Griffiths, Prentice-Hall of India Pvt.Ltd, 2nd editon
6. "Electromagnetics" by Plonsy and Collin
7. "Engineering Electro magnetics" by Nathan Ida, Springer(India) Pvt. Ltd. 2nd Edition.

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## SIMULATION LAB

1. Write program and simulate dynamical system of following models:
   (a) I/O Model
   (b) State variable model
   Also identify time domain specifications of each.
2. Obtain frequency response of a given system by using various methods:
   (a) General method of finding the frequency domain specifications.
   (b) Polar plot
   (c) Bode plot
   Also obtain the Gain margin and Phase margin.
3. Determine stability of a given dynamical system using following methods.
   (a) Root locus
   (b) Bode plot
   (c) Nyquist plot
   (d) Liapunov stability criteria
4. Transform a given dynamical system from I/O model to state variable model and vice versa.
5. Obtain model matrix of a given system, obtain it's diagonalize form if exists or obtain Jordon Canonical form of system.
6. Write a program and implement linear quadratic regulator
7. Design a compensator for a given systems for required specifications.
8. Conduct a power flow study on a given power system.
9. Design a PID controller.
10. Conduct a power flow study on a given power system network using Gauss-Seidel Iterative method.
11. Develop a program to solve Swing Equation.
12. Develop a SIMULINK model for a single area load frequency problem and simulate the same.
13. Develop a SIMULINK model for a two-area load frequency problem and simulate the Same.
14. Design a PID controller for two-area power system and simulate the same.
15. PSPICE Simulation of Single phase full converter using RL and E loads.
16. PSPICE Simulation of Three phase full converter using RL and E loads.
17. PSPICE Simulation of Single phase AC Voltage controller using RL load.
18. PSPICE Simulation of Three phase inverter with PWM controller.
19. PSPICE Simulation of resonant pulse commutation circuit.
20. PSPICE Simulation of impulse commutation circuit.