

M Tech

IN

HIGH VOLTAGE & RENEWABLE ENERGY ENGINEERING

**CURRICULUM
AND
SYLLABI**

(Applicable from 2026 Admission onwards)



**DEPARTMENT OF ELECTRICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT**
Kozhikode-673601, KERALA, INDIA

**The Program Educational Objectives (PEOs) of
M. Tech in High Voltage & Renewable Energy Engineering**

PEO1	Apply enhanced knowledge and skills in the areas of High Voltage AC, DC and renewable energy engineering, so as to excel in various sectors in modern industry/utility and/ or teaching and/or higher education and / or research.
PEO2	Engage in design of novel products and strategic solutions to real life problems in the areas of high voltage and renewable energy engineering that are technically sound, economically feasible and socially acceptable. .
PEO3	Exhibit professionalism, keep up ethics in profession and demonstrate communication skills, leadership qualities as well as willingness to work in groups.

Programme Outcomes (POs) of M. Tech in High Voltage & Renewable Energy Engineering

PO1	Ability to independently carry out research /investigation and development work to solve practical problems
PO2	Ability to write and present a substantial technical report/document
PO3	Ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4	Ability to utilize the acquired knowledge to take up administrative challenges including the management of projects in the field of High Voltage AC, DC and renewable energy engineering having multidisciplinary nature with a perspective to maintain lifelong learning process.
PO5	Willingness and ability to upkeep professional ethics and social values while carrying out the responsibilities as a High Voltage and renewable energy engineer/researcher in devising solutions to real life engineering problems in an independent manner

CURRICULUM

Total credits for completing the M. Tech programme in High Voltage & Renewable Energy Engineering is 75.

The structure of M Tech programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1	Program Core (PC)	25
2	Program Elective (PE)	12
3	Institute Elective (IE)	2
4	Projects	36

The effort to be put in by the student is indicated in the tables below as follows:

L: Lecture (One unit is of 50-minute duration)

T: Tutorial (One unit is of 50-minute duration)

P: Practical (One unit is of one-hour duration)

O: Outside the class effort / self-study (One unit is of one-hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No	Code	Title	L	T	P	O	C	Category
1.	EE6503E	Generation and Measurement of High Voltage	3	0	2	7	4	PC
2.	EE6504E	Advanced Insulation Systems and Semiconductor Packaging	3	0	0	6	3	PC
3.	EE6505E	Renewable Energy Generation	3	1	0	5	3	PC
4.	EE6506E	Numerical Methods for Electromagnetism	3	0	0	6	3	PC
5.		Programme Elective -1	3	0	0	6	3	PE
6.		Programme Elective -2	3	0	0	6	3	PE
7.		Institute Elective	2	-		4	2	IE
		Total Credits	17	1	2	40	21	

Semester II

Sl. No	Code	Title	L	T	P	O	C	Category
1.	EE6515E	AI/Digital Twin Based Condition Assessment of Power Equipment	3	0	2	7	4	PC
2.	EE6516E	Reliability Engineering and	3	0	0	6	3	PC

		Life Estimation of Power Equipment						
3.	EE6517E	HVDC Transmission and Renewable Energy Integration	3	1	0	5	3	PC
4.		Programme Elective -3	3	0	0	6	3	PE
5.		Programme Elective -4	3	0	0	6	3	PE
6.	EE6594E	Renewable Energy Laboratory	0	0	3	3	2	PC
7.	EE6595E	Project Phase I	0	0	3	6	3	PC
		Total Credits	15	1	8	39	21	

Semester III

Sl.No	Code	Title	L	T	P	O	C	Category
1	EE7594E	Project Phase II *	0	0	6	3	3	PC
2	EE7595E	Project Phase III	0	0	30	15	15	PC
Total credits			0	0	36	18	18	

* to be completed during Summer

Semester IV

Sl.No	Code	Title	L	T	P	O	C	Category
1	EE7596E	Project Phase IV	0	0	30	15	15	15
Total credits			0	0	30	15	15	15

List of Electives**

Sl. No	Course Code	Course Title	L	T	P	O	Credits
1	EE6527E	Electromagnetic Transients in AC/DC Grids.	3	0	0	6	3
2	EE6528E	Principles of Electromagnetic Compatibility and PCB Design.	3	0	0	6	3
3	EE6529E	Pulsed Power Engineering.	3	0	0	6	3
4	EE6530E	Design of Magnetics for Electrical Systems.	3	0	0	6	3
5	EE6531E	Condition Monitoring of Power Electronic Converters.	3	0	0	6	3
6	EE6532E	Extra High Voltage AC Power Transmission	3	0	0	6	3
8	EE6201E	Computer Methods in Power System Analysis	3	1	0	5	3
9	EE6202E	Power Converters for Power System Applications	3	1	0	5	3
10	EE6204E	Signal Processing for Power Systems	3	1	0	5	3
11	EE6213E	Digital Protection of Power systems	3	1	0	5	3
12	EE6214E	Power System Economics and Deregulation	3	1	0	5	3

13	EE6226E	Distributed Generation and Micro-Grids	3	0	0	6	3
14	EE6228E	Data Analytics in Power Systems	3	0	0	6	3
15	EE6303E	Modern Digital Signal Processors	3	0	0	6	3
16	EE6323E	Digital Simulation of Power Electronic Systems	3	0	0	6	3
17	EE6327E	Computer Aided Design for Electromagnetic Systems	2	0	2	5	3
18	EE6403E	Artificial Intelligence and Industrial Applications	3	0	0	6	3
19	EE6427E	Sustainable Energy Systems & Design	3	0	0	6	3
20	EE6428E	Distribution Systems Management and Automation	3	0	0	6	3
21	EE6429E	SCADA Systems & Applications	3	0	0	6	3
22	EC6105E	Electronic Product Design	3	0	2	7	4

** List of Electives offered in each semester will be announced by the Department. Any other PG level course approved by the Senate offered in the Institute can also be credited as Programme Elective – 1, 2, 3 and 4 with the prior approval of the Programme Coordinator.

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1	ZZ6001E	Research Methodology	2	0	0	4	2
2	MS6174E	Technical Communication and Writing	2	1	0	3	2
3	IE6001E	Entrepreneurship Development	2	0	0	4	2

** List of Electives offered in each semester will be announced by the Department. Any other PG level course approved by the Senate offered in the Institute can also be credited as Programme Elective – 1, 2, 3 and/ or 4 with the prior approval of the Programme Coordinator.

EE6503E GENERATION AND MEASUREMENT OF HIGH VOLTAGE

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	2	7	4

Course Outcomes:

- CO1: Analyze methods for generating high AC, DC and impulse voltages and currents.
CO2: Detect, measure, and classify partial discharge activity using electrical method
CO2: Evaluate insulation behavior and condition various methods
CO4: Perform and interpret high-voltage tests on electrical apparatus.
CO5: Apply simulation and digital techniques to model HV systems and test circuits.

Insulation Breakdown Phenomena

Gas Dielectric Breakdown: Uniform & non-uniform fields, Paschen's law, Dielectric behaviour at altitudes, Townsend and streamer mechanisms, Corona and electro-negative gas behaviour. Liquid Dielectric Breakdown: Suspended particle mechanism, Bubble & thermal mechanisms. Solid Dielectric Breakdown: Intrinsic, thermal and streamer breakdowns, Electrical treeing. Breakdown behaviour in next generation dielectric materials (nano liquids, higher thermal conductivity solids, ceramic matrix composites, alternates to SF₆)

Generation of High Voltages/Currents

Overview of high voltage technology and laboratory requirements, High voltage waveforms and classifications, Role in power system insulation coordination. AC High Voltage Generation: Testing transformers, Series resonance circuits and high frequency sources. DC High Voltage Generation: Symmetric & asymmetric doubler circuits, Electrostatic machines. Impulse Voltage and Current Generation: Single stage & Marx multistage circuits, Wave shaping, triggering and control, Switching surge generation, Simulation Techniques: Circuit modelling in MATLAB/PSCAD/EMTP.

Measurement Techniques for High Voltages and Currents

Voltage Measurement Techniques: Sphere gaps and correction factors, Resistive, capacitive and mixed voltage dividers, CVT, electrostatic and generating voltmeters. Current Measurement Techniques: Resistive shunts, Magnetic coupling & Hall effect transducers, Rogowski coils (integrating & differentiating). Digital Measurement Techniques: Digital signal conditioning and data acquisition.

High Voltage Testing and Insulation Condition Assessment

Introduction to practical HV testing voltage sources (HV Pulser, High frequency sources, Auto transformers/Variacs, DC sources). DC High Voltage Testing: IR, PI and DC HIPOT tests, Capacitor and equipment testing. AC High Voltage Testing: Dry & wet flashover tests, Pollution tests and PF/tangent delta tests. Oil dielectric breakdown and PD tests (PDIV/PDEV), Cable AC tests (VLF, power frequency). Impulse Testing: Impulse flashover and transformer tests, Oscillogram analysis, Impulse current tests for surge arresters. Measurement standards: AC and Impulse. Application-based testing: 1. choice of electrode geometry- type of electric field, 2. Sea level and altitude level testing, effect of temperature. Condition Assessment: Evaluation of insulation condition under test stress, Criteria for pass/fail and maintenance planning

Laboratory Experiments

1. Simulation of High-Voltage Test Circuits.
2. Modelling and simulation of high-voltage generation and test circuits using MATLAB / PSCAD / EMTP.
3. Measurement of High Voltage Using Sphere Gaps: Impulse BDV of liquids.
4. Measurement of high AC/DC voltages using sphere gap arrangement and application of standard correction factors.
5. PDIV/PDEV and Breakdown (AC) Characteristics of Solid and Liquid Dielectrics.
6. Evaluation of breakdown behaviour of solid and liquid insulating materials under high electric stress.
7. Digital Measurement and Data Acquisition of High-Voltage Waveforms
8. Recording and analysis of high-voltage waveforms using digital signal conditioning and data acquisition systems.
9. Dielectric Spectroscopy of Insulating Materials:
10. Measurement and analysis of frequency-dependent dielectric response of insulating materials and PDC measurements for insulation condition assessment.

11. Partial Discharge Techniques: Testing under different field configurations: point-plane, sphere-plane
12. Detection and measurement of partial discharge using electrical methods and PRPD pattern analysis for classification of insulation defects.

References:

1. Kuffel and Zaengl , High Voltage Engineering Fundamentals, 2nd ed., Newness, 2002
2. M. S. Naidu, V. Kamaraju, High Voltage Engineering, 3rd ed., McGraw-Hill,1995.
3. M. Khalifa, High Voltage Engineering: Theory and Practice, Dekker, 1990.
4. H. M. Ryan, High Voltage Engineering and Testing, IEE 2001.
5. Relevant ASTM, IEEE, IS and IEC standards
6. T. S.Ramu and Chakradhar Reddy, 'Reliability and Life estimation of Power Equipment, New Age International 2009.
7. Kind, D. and Feser, K., High Voltage Test Techniques, Newnes. 2001.

EE6504E ADVANCED INSULATION SYSTEMS AND SEMICONDUCTOR PACKAGING

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

- CO1: Understand the basic principles and classification of electrical insulation materials and systems.
CO2: Explain dielectric behavior and common aging mechanisms in electrical insulation.
CO3: Apply insulation design concepts such as creepage, clearance, and electric field control in electrical systems.
CO4: Identify insulation and packaging challenges in compact and power electronic systems.
CO5: Perform basic insulation testing and diagnostic measurements.

Electrical Insulation Materials and Dielectric Behavior

Classification of insulation systems – solid, liquid, gaseous insulation. Common insulating materials: polymeric insulation (epoxy, XLPE, polyimide), ceramic, and glass insulation – Dielectric behavior: polarization mechanisms, dielectric constant and dielectric loss, dielectric strength, breakdown mechanisms. Basic aging mechanisms: electrical aging, thermal aging, effects of moisture, and environmental contamination. Introduction to partial discharge. Insulation of electrical motors: stator and rotor insulation systems.

Insulation Design and Packaging of Electrical Systems

Insulation design concepts: creepage and clearance, electric field distribution, basic stress control methods, and insulation coordination. Overview of relevant IEC and IEEE standards. Packaging of electrical and power electronic systems: insulation challenges in power converters, insulation in power modules, basic packaging materials, and substrates.

Insulation issues in high-frequency components: transformers and inductors. Applications: insulation requirements in electric vehicles, renewable energy systems, and industrial power electronics.

Insulation Systems and Packaging Laboratory

1. Insulation resistance measurement.
2. Thermal aging study of insulation samples.
3. Basic electric field simulation for insulation design.
4. Mini Assignment / Case Study: Basic insulation design or failure analysis of a given electrical or power electronic system.

References

1. Kind, D. and Feser, K., High Voltage Test Techniques, Newnes. 2001.
2. Naidu, M.S. and Kamaraju, V., High Voltage Engineering, McGraw-Hill. 2007.
3. Dissado, L.A. and Fothergill, J.C., Electrical Degradation and Breakdown in Polymers, IEE Press. 1992.
4. IEC and IEEE Standards on Electrical Insulation (Selected Sections).

E6505E RENEWABLE ENERGY GENERATION

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	1	0	5	3

Course Outcomes:

- CO1: Identify various renewable energy sources and their current status of application.
 CO2: Understand the fundamentals and fabrication techniques of solar cell.
 CO3: Evaluate wind and solar energy generation capacity with respect to plant site.
 CO4: Understand the application of hydrogen as energy source and design energy storage systems.

Introduction to Renewable Energy Sources

Conventional energy sources-Depletion of conventional energy sources and their impact- Environmental aspects of energy utilization-Energy efficiency and energy conservation- Renewable energy resources-Indian energy scenario-Global energy scenario- Energy consumption and its relation to economics of countries-Energy transition-Source of energy in the sun- Sun-Earth geometric Relationship- Apparent Path of the Sun-Electromagnetic Radiation-Extra-terrestrial Solar Radiation-Terrestrial Solar Radiation- Solar Spectral Distribution-Measurement of Terrestrial Solar Radiation-Manifestation of solar energy in different forms of energy

Solar Cell and Photovoltaic Technologies

Solar Cell Structure- Light generated Current- Light IV Characteristics- Solar cell parameters- Spectral Response and Quantum Efficiency- Effect of Series Resistances and Shunt Resistances on solar cell I-V characteristics- Effect of Temperature and Light Intensity- effect of shading- Losses in solar cells-Generation recombination in semiconductors Shockley- Read and Hall expression; Surface and interface recombination; Schockley-Queissser limit of efficiency-Cell Fabrication Technologies-Silicon Source Material- Wafers- Cleaning- Texturing-Testing and Module Fabrication

Wind Energy Generation

Pressure gradient and coriolis forces -Atmospheric boundary layer - Atmospheric stability- Basic concepts of wind energy converter - surface wind characteristics and related parameters- Wind data assessment and selection of prospective wind energy sites- Estimation of wind energy- Energy equation- Types of wind energy converters or turbines- Different components of wind turbine- selection of turbine rotors

Battery and Hydrogen based Energy Systems

Battery Energy Storage Systems (BESS) -Battery electrical models (Li-ion, LFP, flow)-Hydrogen Energy Systems - Electrolyzer interfacing converters (PEM, Alkaline)-Fuel cell grid integration-Hydrogen as long-duration storage (LDES)-Hybrid Renewable-Battery-Hydrogen Systems-Various routes of hydrogen generation- Electrochemical-Electrolysis- photo electro chemical- PM based electrolyzer- Photo electrolysis- Photocatalytic- Biological-Anaerobic digestion reactions-oxidation and reduction- Multi-timescale energy management

References:

1. J. Twidell, T. Weir, Renewable Energy Resources, Taylor and Francis, 4th Edition, 2021.
2. G. Boyle (Editor), Renewable Energy: Power for a Sustainable Future, Oxford University press, 3rd Edition, 2012.
3. G. N. Tiwari, Solar Energy, Fundamentals, Design, Modeling and Applications, Narosa, 2006.
4. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, John Wiley, 4th Edition, 2013.
5. R. Gasch, J. Twele, Wind Power Plants: Fundamentals, Design, Construction and Operation, Springer, 2nd Edition, 2012.
6. J N Roy and D N Bose: Photovoltaic Science and Technology, Cambridge University Press, 2018.
7. S.M. Mueen, Wind energy Conversion systems, Springer, 2012.

EE6506E NUMERICAL METHODS FOR ELECTROMAGNETISM

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Understand vector spaces, matrices, and systems of linear equations.

CO2: Use numerical techniques to obtain approximate solutions of algebraic and Differential equations.

CO3: Develop new methods and software for finite difference and finite element differential equation models as well as charge simulation method for frequency domain models.

Basic Field Theory

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

Linear Algebra and Numerical Methods

Systems of linear equations and their solutions. Gaussian elimination and Gauss-Jordan method. Matrices and matrix operations. Vector spaces and subspaces. Linear independence and dependence Errors in numerical computations. Types and sources of errors. Solutions of algebraic and transcendental equations using the bisection method, regula falsi method, Newton- Raphson method, and secant method. Numerical differentiation and numerical integration using the trapezoidal rule and Simpson's rule. Numerical solution of ordinary differential equations using the Euler method and Runge-Kutta methods.

Numerical Field Computation

Solution by numerical methods- Finite Difference Method- 1D and 2D planar and axial symmetry problem, Finite Difference Time Domain Method (FDTD): The FDTD grid and the Yee Algorithm, Numerical Stability of FDTD, Absorbing and perfectly matched layers., Charge Simulation Method- 3D and 2D axial symmetry problem.

FEM, MoM and BEM

Finite element method (FEM) – Differential/ integral functions –Variational method –Energy minimization– Discretisation – Shape functions , Method of Moments (MoM): Integral equations, Green's functions, applications to radiation and scattering problems. Boundary Element Method (BEM)

References

1. S. Chakravorti, '*Electric Field Analysis*', published by CRC Press (Taylor & Francis), USA, 2015, 1st Ed.
2. Karl E. Lonngren, Sava V. Savov, Randy J. Jost, '*Fundamentals of Electromagnetics with MATLAB*', 2nd edition, SciTech Publishing, Inc., 2007.
3. JaanKiusalaas, '*Numerical Methods in Engineering with Python*', Cambridge University Press, 2nd edition, 2010.
4. Chen, Cao and Mittra, '*Multiresolution Time Domain Scheme for Electromagnetic Engineering*', Wiley, 1st edition, 2005.
5. A Daniel G. Swanson, Wolfgang J.R. Hoefer, '*Microwave circuit modelling using electromagnetic field simulation*', Artech House, 2003.
6. Sergey N. Makarov, '*Antenna and EM Modelling with Matlab*', Wiley, 2002.

EE6515E - AI/DIGITAL TWIN BASED CONDITION ASSESSMENT OF POWER EQUIPMENT

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	2	7	4

Course Outcomes:

- CO1. Formulate physics-based digital twin models of transformers, cables, GIS and rotating machines.
 CO2. Extract features from diagnostic data and update twin states using estimation algorithms.
 CO3. Integrate electrical and chemical monitoring results into degradation and life-prediction models.
 CO4. Design digital twin frameworks for predictive maintenance.

Digital Twin Architecture & Multiphysics Foundations

Digital Twin Fundamentals: Digital Twin Vs Digital Shadow; Cyber-Physical Systems; Lifecycle Twin Concept; Role in Smart Grids and Asset Management. Physics Foundations for Power Equipment: Thermal Ageing of Insulation; Arrhenius Law; Electric-Field Stress Models; Moisture Diffusion in Solids; Dielectric Relaxation Phenomena. Data Foundations: Sensor Networks; SCADA; Time-Series Databases; Uncertainty and Missing Data; Synchronization; Data Validation. Hybrid Modeling: Combining Governing Equations with Machine Learning; Physics-Informed Neural Networks (Pinns); Parameter Identification. Digital-Twin Integration: Defining State Variables, Measurement Models, and Update Loops.

Electrical Diagnostics & Partial-Discharge-Driven Digital Twins

Dielectric Physics: Polarization Mechanisms; Relaxation Models; Frequency dependent Permittivity. Diagnostic Techniques: PDC, RVM, FDS, FRA—Instrumentation and Parameter Extraction. Partial Discharge Physics: Streamer Formation; Treeing Initiation; Space Charge Effects. Sensing & Signal Processing: HFCT, Rogowski Coils, Acoustic and UHF Sensors; Denoising; Pulse Clustering. Twin Coupling: Mapping Diagnostics To Insulation Parameters; PD-Based Severity Indices; State Estimation; Trend Analysis.

Hybrid AI: PD Pattern Classification Using Neural Networks; Physics Informed Feature Selection

Transformer Digital Twin

Chemistry, Moisture and Thermal-Electrical Models, Oil-Paper Insulation Physics: Thermal Ageing Kinetics; Cellulose Depolymerization; Moisture-Dependent Breakdown Strength. Chemical Diagnostics: DGA Interpretation; Duval Triangle and Pentagon; Furan Analysis; DP Estimation; Gas-Generation Kinetics. Moisture Modeling: Diffusion Models; Equilibrium Curves (ABB, Serena); Moisture Migration; Drying Strategies.

Thermal-Electrical Twin: Hot-Spot Models; Load Cycles; Ageing Acceleration Factors.

Data-Driven Layer: Regression Models for DP Estimation; Bayesian Inference for Moisture; Anomaly Detection in Gas Ratios. Twin Updating: Calibration from Historical Data; Uncertainty Propagation; Remaining-Life Prediction.

Cable, GIS & Rotating Machine Digital Twins and Fleet-Level Analytics

Cable Insulation Physics: Water Treeing; Electrical Tree Growth Models; PD based Localization; TDR.

GIS Multiphysics: SF6 Dielectric Properties; Gas Decomposition Chemistry; Leakage Modeling; PD Propagation.

Rotating Machines: Electromagnetic-Thermal-Mechanical Coupling; Stator Ageing; Rotor Asymmetry; Vibration Models.

Fleet-Level Digital Twins: Risk Models; Health Indices; Failure Probability Curves; Maintenance Optimization.

Cyber-Physical Integration: Digital Substations; Cybersecurity; Cloud Deployment.

Capstone Digital Twin Design: Full Twin Architecture for One Asset.

References:

1. S.Chakravorti, D.Dey, B.Chatterjee, Recent Trends in the Condition Monitoring of Transformers, Springer, 2013.
2. Q. Su, R.E.James, Condition Assessment of High Voltage Insulation in Power System Equipment, IET 2008.
3. T.S. Ramu, Partial Discharge Based Condition Monitoring of High Voltage Equipment, New age International Publishers, 2010.
4. Grieves, M.W., Digital Twins: Past, Present, and Future, Springer, 2023.
5. R. J. Hamidi, "Digital Twins for Power Transformers," 2023 IEEE Power & Energy Society General Meeting (PESGM), Orlando, FL, USA, 2023.
6. B. Gao, H. Liu, H. Su, Z. Hong, C. Ji and M. Zhao, "Design and typical application of digital twin architecture in Smart Grid," 2022 7th Asia Conference on Power and Electrical Engineering (ACPEE), Hangzhou, China, 2022.
7. Picher, Patrick. "Use of Digital Twins for Transformers and Reactors." *Transformer and Reactor Life Management*. Cham: Springer Nature Switzerland, 2024. 381-405.
8. CIGRE Digital twin related articles and technical brochures.

EE6516E - RELIABILITY ENGINEERING AND LIFE ESTIMATION OF POWER EQUIPMENT

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

- CO1 Determine the reliability of a product/system by applying the knowledge of probabilistic concept.
- CO2 Identify various failure models and time dependent reliability
- CO3 Apply different reliability testing methods
- CO4 Understand the factors that affects the reliability of electrical insulation systems

Basic Concepts

Basic concepts – Why Reliability analysis is required-Reliability functions $f(t)$, $F(t)$, $R(t)$, $h(t)$ – Relationship between these functions – Bathtubs curve – Exponential failure density and distribution functions - Expected value and standard deviation of Exponential distribution – Measures of reliability – MTTF, MTTR, MTBF Stochastic transitional Probability matrix – time dependent probability evaluation –Limiting State Probability evaluation – Absorbing states – Markov Processes-Modelling concepts – State space diagrams – time dependent reliability evaluation of single component repairable model

Reliability Evaluation

Rules for combining Probabilities of events – Failure Density and Distribution functions –Bernoulli's trials – Binomial distribution – Expected value and standard deviation for binomial distribution –Evaluation of network Reliability / Unreliability – Series systems, Parallel systems, Series -Parallel systems, partially redundant systems – Types of redundancies - Evaluation of network Reliability /Unreliability using conditional probability method.

Life Estimation Methods

Exponential, Weibull distribution, , Normal distribution and lognormal distribution – Other types of distributions-Sampling distribution - Correlation – The concept of Correlation, measuring correlation - Auto and cross correlation functions – Properties-Reliability Life Testing - Test time calculations, Burn-in testing, Acceptance testing, accelerated life testing and Experimental Design - Reliability Growth Testing - Growth process, Idealized growth curve and other growth modals. Goodness of Fit tests - Chi-square goodness of fit test, Bartlett's test for the exponential distribution, Mann's test for the weibull distribution, kolmogorov-smirnov test for normal and lognormal distributions and tests for the power law process model.

Life Estimation of Electrical Insulation

Lifetime estimation of electrical Insulation-Accelerated aging-Millers theory-Single stress model- Arrhenius model of aging -Multi stress Model- Simon's, Fallau and Montanari's Model-Statistical Analysis for Life estimation-Probability plotting-regression techniques-Maximum likelihood estimation-Factors affecting lifetime of transformers-Degree of Polymerization-Moisture-Dielectric Spectroscopy- Factors affecting lifetime of cables

References:

1. E Balagurusamy, Reliability Engineering, Tata McGraw-Hill, 2017.
2. S. K. Sinha, Reliability and Life Testing, Wiley Eastern Ltd., 1986.
3. Charles E. Ebeling, Reliability and Maintainability Engineering, Tata McGraw-Hill.
4. Ronald Deep, Probability and Statistics, Elsevier Publishers.
5. Pierre Dersin, Modeling Remaining Useful Life Dynamics in Reliability Engineering, Taylor & Francis, 2023.
6. R. K. Saket, Sanjeevi Padmanaban, Reliability Analysis of Modern Power Systems, Wiley , 2024.

EE6517E HVDC TRANSMISSION & RENEWABLE ENERGY INTEGRATION

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	1	0	5	3

Course Outcomes:

- CO1: Understand various VSC Topologies used in Renewable Energy Grid Integration & attain deep understanding of the operation and performance of Two-Level Single phase and Three phase VSCs under various modulation schemes.
 CO2: Understand the operation of three-level NPC VSCs and MMC VSC used in HVDC Transmission.
 CO3: Differentiate the advantages and disadvantages of HVAC and HVDC Transmission Systems & explain various types and applications of HVDC Transmission Links and BTB Links
 CO4: Explain the Operation of LCC Based HVDC Links and their Control Strategies.
 CO5: Understand the Operation of MTDC Systems and their Control with specific reference to Offshore Wind Farm Grid Integration

Voltage-Sourced Power Converters (VSC) for Renewable Energy Grid Integration

Power Electronic Converters & Converter Systems: PE Switches – Switch Classification, Switch Characteristics, Classification of Converters – based on commutation process, based on terminal voltage & waveforms, Voltage-Sourced Converters (VSC) – Basic configurations.

Single Phase Two-Level VSC :

Half-bridge and Full-bridge Single Phase VSC with square wave switching, Harmonic performance, Sinusoidal Pulse Width Modulation (SPWM) for Single Phase half-bridge and full-bridge VSC, Bipolar versus Unipolar SPWM, Harmonics and filtering, Leakage current issue in SPWM Single Phase Inverters fed from Solar Panels, The H5 Inverter for Photovoltaic application

Three Phase Two-Level VSC: SPWM for 2-Level three-phase VSC – harmonics; choice of carrier frequency; DC Voltage utilisation; third harmonic injection; filtering requirements,

Space Vector Modulation (SVM):

Motivation for SVM for Three-phase Two-Level VSC, Switching States, Space Vectors, Dwell Time calculation, Modulation Index, Switching Sequence, Spectrum Analysis, Even Harmonic Elimination, Discontinuous SVM

Introduction to Current Regulated Two-Level VSC:

Application of Current-regulated VSCs in Power Systems – Grid side current regulation in a grid-connected single-phase two-level PWM inverter by hysteresis control – Hysteresis current control in grid-connected three-phase two-level PWM Inverter – Disadvantages of hysteresis current control

Some Advanced VSCs for Renewable Energy Grid Integration & HVDC Transmission

Diode Clamped Multilevel Inverters : Three Level Single Phase Half Bridge Neutral Point Clamped (NPC) VSC, PWM Scheme for Half Bridge NPC - Harmonic performance, Three Level NPC Three Phase VSC with impressed DC Voltages, NPC VSC with Capacitive DC Side Voltage Divider – Partial DC Side Voltage drift; DC Side Voltage Equalisation; DC Side Currents

Space Vector Modulation for NPC VSC

Introduction to Modular Multilevel Converter Based VSC: Half-Bridge MMC Converter Operation – Capacitor Voltage Balancing Problem – Capacitor Voltage Balancing by Sequence Rotation – Capacitor Voltage Balancing by Min/Max Criterion – Nearest Level Modulation (NLM) for Sinusoidal Output in MMC – Techniques to implement NLM – Voltage Balancing by Capacitor Voltage Sorting.

Introduction to LCC Based HVDC Transmission System

Description of HVDC Transmission Systems – Types of DC Links – Monopolar Link – Bipolar Link – Homopolar Link – Ground return versus Metallic return – HVDC Transmission Link versus HVDC BTB (Back-to-Back) Link – Types of Converters: Line Commutated Converter – Voltage Source Converters – Description of various VSC topologies used in practice – Description of various components in a LCC based HVDC Link

Comparison of AC and DC Transmission – Limitations of AC System – Advantages of HVDC Transmission – Disadvantages of HVDC Transmission – Applications of HVDC Links and HVDC BTB Stations with examples of existing installations for various applications -Evolution of HVDC Systems in India – Technical details of all existing HVDC Links and BTBs in India.

6-Pulse LCC with Mode-1 commutation overlap: Mode-1 Commutation Overlap and Voltage Notching in Six-Pulse Converter in Rectifier Operation

6-Pulse LCC in Inversion mode: Commutation Overlap in Inverter Operation of a Six-Pulse Converter, Commutation Failure in Inverter

Introduction to LCC Based HVDC Link Control: Steady-state equivalent circuits of a LCC HVDC Link – Steady-state relations for Rectifier mode and Inverter mode in terms of firing angle, firing advance angle and extinction angle – Current Margin Control principles – Link DC Voltage Control – Constant Extinction Angle Control

VSC Based HVDC Links and their Control

VSC HVDC Link: Voltage Source Converters – Advantages of VSC HVDC System – Disadvantages of VSC HVDC System – Comparison with LCC Based HVDC System – Overhead and Subsea/Underground VSC HVDC Transmission – DC Cable types with VSC HVDC – Monopolar and Bipolar VSC HVDC Topologies – VSC HVDC System Components

Two-Level SPWM VSC HVDC Converter Control: Converter Control objectives : DC Side Voltage Control, DC Side Power Control, AC Side PCC Voltage Control, AC Side Reactive Power Control – Link Control in dq domain – Model of AC Side in dq domain – Model of DC Side in dq domain – Decoupling feedback in dq domain - Control block diagrams in dq domain for P_{dc} control, V_{dc} Control and PCC Voltage Control

Two-Level SPWM VSC HVDC Link Control: Control strategies for two-terminal VSC HVDC Links: Master-Slave Control Scheme – Voltage Margin Control Scheme – Handling of abnormal conditions in Voltage Margin Control – Voltage Margin Control Scheme using Dynamic Saturation Limits

Introduction to MTDC Systems

MTDC Systems – Potential Applications of MTDC Systems – Types of MTDC Systems – The $\pm 800\text{kV}$ 6000MW NER-Agra MTDC Project in India – A Voltage Margin Control Strategy for NER-Agra MTDC System – Proportional Power Sharing in Inverters in a MTDC System – Two-Stage Voltage Margin Control at Inverters – Implementation of Two-Stage Voltage Margin Control – Priority Power Sharing and its implementation – VSC Based MTDC Systems for Integration of Off-shore Wind farms with On-shore Grids – Power despatch schemes for such a system: Proportional sharing, Priority sharing, Fixed sharing – Voltage Margin Control strategies for implementing various power sharing schemes in an example wind farm integration MTDC – DRU HVDC for Offshore Integration

References:

1. 'Voltage-Sourced Converters in Power Systems', Amirnaser Yazdani & Reza Iravani, IEEE Press, John Wiley & Sons, 2010
2. 'High Power Converters and AC Drives', Bin Wu, IEEE Press, John Wiley & Sons, 2006
3. 'Grid Converters for Photovoltaic and Wind Power Systems', Remus Teodorescu, Marco Liserre & Pedro Roderiguez, IEEE Press, John Wiley & Sons, 2011
4. 'Understanding FACTS', Narain G. Hingorani & Laszlo Gyugyi, IEEE Press, 2000.
5. 'Power Electronics', Ned Mohan, William P. Robbins & Tom M. Undeland, John Wiley & Sons.
6. 'Power Electronics', Muhammad H. Rashid, Third Edition, Pearson Education, 2004
7. 'High Voltage Direct Current Transmission – Converters, Systems and DC Grids', Dragan Jovcic and Khaled Ahmed, John Wiley & Sons, 2015 (Recommended as primary reference book for HVDC Content)
8. 'HVDC Transmission – Power Conversion Applications in Power Systems', Vijay K. Sood et.al., IEEE Press, John Wiley & Sons, 2009
9. 'HVDC Power Transmission Systems', K R Padiyar, New Age International Publishers, 3rd Edition, 2015
10. Ismunandar, C., Meer, van der, A. A., Gibescu, M., Hendriks, R. L., & Kling, W. L. (2010). Control of multi-terminal VSC-HVDC for wind power integration using the Voltage-Margin method. In Proceedings of the 9th International Workshop on Large-Scale Integration of Wind Power Into Power Systems As Well As On Transmission Networks for Offshore Wind Power Plants, 18-19 October 2010, Quebec, Canada (pp. 1-8). Hydro Quebec. (for Module 5)
11. Lujie Yu et.al, "DRU-HVDC for Offshore Wind Power Transmission – A Review", IET Renewable Power Generation, 2024;18:2080-2101 (for Module 5)
12. Roland Ryndzionek & Lukasz Sienkiewicz, 'Evolution of HVDC Link Connecting Offshore Wind Farms to Onshore Power Systems', Energies 2020, 13, 1914; doi:10.3390/en 13081914 (for Module 5)
13. Asimenia Korompili et.al., 'Review of VSC HVDC Connection for Offshore Wind Power Integration', Renewable and Sustainable Energy Reviews, 2016, DOI: 10.1016/j.rser.2016.01.064 (for Module 5)
14. Zhou Li et.al., 'Recent Developments in HVDC Transmission Systems to Support Renewable Energy Integration', Global Energy Interconnection, Vol 1, No. 5, Dec 2018, pp 595-607 (for Module 5)

EE6594E: RENEWABLE ENERGY LABORATORY

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

- CO1. Design and realize magnetic components and power converters used in renewable energy systems.
- CO2. Implement control techniques for power electronic converters used in renewable energy integration.
- CO3. Analyze performance characteristics of solar photovoltaic systems and power converters.
- CO4. Design and test inverter and bidirectional converter systems for grid and storage integration.

List of Experiments

1. Design and realization of high-frequency transformer and inductor for power converters.
2. Design and implementation of PWM control using TL494 timer IC.
3. PCB layout design of a buck converter.
4. Testing and performance evaluation of a buck converter.
5. Evaluation of V I and P V characteristics of a solar photovoltaic module.
6. Implementation of the maximum power point tracking algorithm for a solar photovoltaic system.
7. Design and development of a single-phase inverter.
8. Study and implementation of a dual active bridge converter for bidirectional power flow.

References

1. Erickson R W and Maksimovic D, Fundamentals of Power Electronics, Springer.
2. Rashid M H, Power Electronics Circuits Devices and Applications, Pearson.
3. Mohan N, Undeland T M and Robbins W P, Power Electronics Converters Applications and Design, Wiley.

EE6595E PROJECT-PHASE I

Pre-requisites: **NIL**

L	T	P	O	C
0	0	3	6	3

Course Outcomes:

- CO1: Identify and review research papers for understanding emerging technologies in the field of high voltage engineering.
- CO2: Identify a research problem in the areas of control and/or instrumentation systems and its feasible solutions by summarizing the reviewed papers.
- CO3: Demonstrate the identified problem and its feasible solutions through basic simulations or experiments.
- CO4: Document the identified problem and its feasible solutions through a detailed report and demonstrate through an oral presentation.

Each student has to choose a topic in the field of high voltage engineering, outside the M. Tech syllabus and identify relevant literature. Students have to identify a research problem in the field and study the feasible solutions available in the literature. Basic experiments and/or simulations may be used for this. Students have to submit a detailed report of the work and give an oral presentation before a panel of examiners.

EE7594E PROJECT –PHASE II

Pre-requisites: **NIL**

L	T	P	O	C
0	0	6	3	3

Course Outcomes:

CO1: Review literature on any topic in the fields of high voltage engineering and formulate a research problem.

CO2: Apply relevant techniques and tools to arrive at feasible solutions for the problem formulated

CO3: Evaluate the solutions developed through simulations and/or experiments.

CO4: Document the problem formulation and its feasible solutions through a detailed report and demonstrate through an oral presentation.

Each student has to identify and formulate a research problem in the fields of high voltage engineering, develop solutions for it and validate the solutions through experiments and/or simulations. This project shall be a continuation of Project Phase I. Students have to submit a detailed report of the work and give an oral presentation before a panel of examiners.

EE7595E PROJECT –PHASE III

Pre-requisites: **NIL**

L	T	P	O	C
0	0	30	15	15

Course Outcomes:

CO1: Identify a research topic in the area of high voltage engineering, conduct literature survey, formulate the problem, and state the objectives.

CO2: Design and implement control techniques and/or instrumentation systems for the selected process/problem.

CO3: Apply new tools and techniques for development of cost effective and environment friendly designs in the areas of control and/or instrumentation systems.

CO4: Document the work through a technical project report, and publishing in reputed conferences/journals and oral presentations before a panel of examinations.

Project Phase III may or may not be the continuation of Project Phase I and/or Project Phase II. Faculty members propose projects/broad area of work and student will be asked to meet the faculty member who is offering the project of interest for guidance. Student can also select the topic after discussions with guide. Students are encouraged to take up interdisciplinary project too. Students can carry out their projects in R&D organizations/ industries which have facility in the proposed area with an officer from there as the external guide and a faculty from the department as internal guide. Students are required to undertake detailed technical work in the chosen area using one or more of the following: (i) Analytical models (ii) Computer simulations (iii) Hardware implementation. The complete project report is not expected at the end this semester. However, a 30-40 page typed report based on the work done will have to be submitted by the students to the assessing committee.

EE7596E PROJECT –PHASE IV

Pre-requisites: **NIL**

L	T	P	O	C
0	0	30	15	15

Course Outcomes:

CO1: Develop comprehensive solutions to the issues identified in previous semester work and meet the requirements as stated in the objectives.

CO2: Demonstrate and validate the developed solutions through simulations and/or experiments.

CO3: Analyze the results critically, interpret the results and justify the achievement of the stated objectives.

CO4: Summarize the results and effectively communicate the research contribution and publish in reputed Journals /Conferences.

Project Phase IV may be continuation of Project Phase III. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their research contributions in reputed conferences and/or journals.

EE6527E ELECTROMAGNETIC TRANSIENTS IN AC/DC GRIDS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Model AC lines and HVDC cables using distributed concepts and analyse travelling-wave reflections/refractions.

CO2: Analyze switching and lightning overvoltages and apply insulation coordination and surge arrester placement concepts.

CO5: Explain DC fault evolution (di/dt , dv/dt , capacitor discharge) and interpret pole-to-ground and pole-to-pole fault waveforms.

CO6: Describe DC protection philosophy and DC circuit breaker principles; propose protection sequences and mitigation measures.

EMT Fundamentals and Modelling Foundations

EMT vs electromechanical transients: time scales and dominant physics- Lumped vs distributed modelling; validity and assumptions - RLC network modelling; state-space overview and interpretation of natural response- Numerical integration concepts for EMT (step size, stability, stiffness – qualitative)- Switching functions; ideal vs non-ideal switches (overview)- Nonlinear elements in EMT context: surge arrester V-I characteristic and transformer saturation (concept)- EMT waveform interpretation: oscillations, damping, dominant frequency, ringing.

Travelling Waves in AC Lines and HVDC Cables

Travelling wave basics: surge impedance, propagation velocity, energy transport- Reflection and refraction at terminations; reflection coefficients (open/short/mismatch)- Switching surges in overhead lines; TRV concept and switching severity factors (overview)- Underground cables: distributed parameters; terminations; sheath/armour influence (overview)- Frequency-dependent effects: skin and proximity effects (concept) and impact on transients- HVDC cable transient behaviour: cable-end overvoltages and resonance with connected equipment- Overvoltage protection placement principles for line/cable ends and station interface Switching Transients in HV Equipment and

Insulation Coordination

Circuit breaker switching phenomena: current chopping, restrike, pre-insertion resistors (overview)- Transformer energization: inrush, overvoltage, sympathetic inrush (intro level)- Capacitor bank and shunt reactor switching transients- Ferroresonance: conditions, recognition, and practical mitigation (intro)- Lightning overvoltages and impulse concepts; insulation coordination philosophy (BIL/basic concepts)- Surge arrester behaviour (MOV): protective level and energy absorption concept- Mitigation approaches: damping resistors, controlled switching (concept), shielding/grounding overview- Case-study approach: identifying source of ringing frequency and proposing mitigation.

DC Grids—Fault Transients, Protection and DC Circuit Breakers

DC fault types: pole-to-ground, pole-to-pole; high-impedance fault concept- DC fault evolution and waveform signatures: DC-link capacitor discharge, cable discharge, source contribution (waveform-level)- Why DC faults rise fast: di/dt , dv/dt , and absence of natural current zero- DC grid grounding options (overview) and effect on fault signatures- Protection philosophies: non-selective (converter blocking) vs selective isolation- Fault detection concepts: local di/dt & dv/dt , differential (concept), travelling-wave (concept)- DC circuit breaker principles: mechanical, solid-state, hybrid; speed vs losses trade-offs- Protection sequence coordination: detection → breaker trip → isolation → recovery; timing sensitivity- Mitigation: current limiting reactors, MOV energy absorption, breaker timing and selectivity considerations.

References:

1. A. Greenwood, Electrical Transients in Power Systems, Wiley & Sons Inc. New York, 2010
2. H. W. Dommel, EMTP Theory Book, Microtran Power System Analysis Corporation, 1992
3. Venkata Dinavahi, Ning Lin, Real-Time Electromagnetic Transient Simulation of AC–DC Networks, Wiley, 2021.
4. Pritindra Chowdhari, Electromagnetic Transients in Power System, John Wiley, Second Edition, 2009
5. V.K. Sood, HVDC and FACTS Controllers- Applications of Static Converters in Power System, Kluwer, 2004
6. R.D. Begamudre, Extra High Voltage AC Transmission Engineering, Wiley, 2006.
7. CIGRE Technical Brochure 873, Design, Test and Application of HVDC Circuit Breakers, 2022.
8. PSCAD/EMTDC or EMTP user documentation (for modelling practice, as per availability)

EE6528E: Principles of Electromagnetic Compatibility and PCB Design

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Define EMI Environment, Coupling principles, Different sources of EMI and Mitigation Techniques.

CO2: Summarize the methods of mitigation of EMI issues

CO3: Examine the PCB design and the challenges faced by it due to EMI

Basics of EMI/EMC:

Basic concepts Definition of EMI and EMC with examples, Classification of EMI/EMC - CE, RE, CS, RS, Units of Parameters , Need for Electromagnetic Compatibility, two aspects of EMC – Emission and Susceptibility, Radiation and Conduction, EMC standards and regulations, Designing for Electromagnetic Compatibility - Noise and Interference, Typical Noise path, Methods of noise coupling - Capacitive and Inductive Coupling,

Mitigation of EMI/EMC:

Effect of Shielding on capacitive and inductive coupling, Shielding to prevent magnetic radiation, shielding a receptor against magnetic fields, Shield Transfer Impedance -shielding properties of various cable configurations, coaxial cable and shielded twisted pair, braided shields, ribbon cables, Shield Terminations - Safety grounds, signal grounds, single point, multi-point and hybrid grounds, Chassis Grounds, Common Impedance Coupling, Grounding of cable shields, Ground loops and its breaking, Common Mode Choke – Analysis at low and high frequencies, Balancing and Filtering, Isolation transformer, opto isolator.

EMC standard and regulations

EMC standard and regulations National and International standardizing organizations- FCC, CISPR, ANSI, OD, IEC, CENECE, FCC CE and RE standards, CISPR, CE and RE Standards, IEC/EN, CS standards, Frequency assignment - spectrum conversation

PCB design and its challenges:

PCB layout and stack up - General PCB layout Considerations, PCB to chassis ground connections, return path discontinuity, PCB layer stack up, General PCB design procedure, mixed signal PCB layout, Split planes, Ground connection and power distribution, vertical isolation - Near fields and far fields, characteristic and wave impedances, shielding effectiveness, absorption and reflection loss, shielding with magnetic material, apertures, conductive gaskets, conductive windows, conductive coating, grounding of shields - Electrostatic Discharge (ESD) -Static generation, human body model, static discharge, ESD protection in equipment design, Transient and Surge Protection Devices, ESD grounding, non-grounded products, software and ESD protection, ESD versus EMC, ESD Testing

References:

1. Henry W.Ott, Electromagnetic Compatibility Engineering, John Wiley & Sons, 2009.
2. Henry W.Ott, Noise Reduction Techniques in Electronic Systems, Second Edition, Wiley Interscience Publication, 1988.
3. Clayton R.Paul, Introduction to Electromagnetic Compatibility, Second Edition , Wiley Interscience Publication, 2006.
4. V. Prasad Kodali, Engineering Electromagnetic Compatibility: Principles, Measurements, Technologies, and Computer Models, Second Edition, IEEE Press, 2001.
5. Ralph Morrison, Grounding and Shielding circuits and interference, Fifth Edition, Wiley, 2007.
6. Tim Williams, EMC for Product Designers, Newnes, 5th Edition, 2016.
7. Bruce R. Archambeault, PCB Design for Real-World EMI Control, Springer, 2002

EE6529E PULSED POWER ENGINEERING

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Analyse various circuits for generating pulsed power signals

CO2: Design suitable insulation systems for pulsed power sources

CO3: Design pulsed power circuits for various application

Introduction to Pulsed Power Systems

Introduction to pulsed power systems (examples and applications), Energy storage (capacitive, inductive, kinetic, chemical), Voltage multiplier circuits (Marx generators, Blumlein generators, and spiral generators, etc.), Transmission lines and pulse forming networks, Pulse transformers, Pulse modulators Magnetic pulse compression, FCG, Explosively driven FCGs, Homopolar generators. Power conditioning systems.

Insulation Requirements for Pulsed Power Systems

Insulation requirements for pulsed power systems - gaseous, liquid, solid and magnetic insulation and their behaviour under pulsed voltages. Measurement techniques of pulsed power parameters, safety of circuits, Pulsed power materials, High speed diagnostics (voltage, current, plasma, magnetic field, etc.)

High Power Switches

High power switches: spark gaps, low pressure switches, liquid and solid state switches, solid stage switches, magnetic switches, opening switches, Electromagnetic field analysis of pulsed power circuits

Applications

High Power Microwaves, mass drivers, pollution control, food processing, particle accelerators, lasers, manufacturing, Nuclear electromagnetic fields, High voltage hazards and accidents.

References :

1. Hansjoachim Bluhm ,*Pulsed Power Systems*, Springer, 2006.
2. Pai and Zhang, Introduction to High Power Pulse Technology, World Scientific Publishing, 1995.
3. Martin et al., J. C. Martin on Pulsed Power, Plenum Press, 1996.
4. G.A. Mesyats, *Pulsed Power*, Kluwer Academics/Plenum 2005.

EE6530E DESIGN OF MAGNETICS FOR ELECTRICAL SYSTEMS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Understand magnetic materials, core structures, and loss mechanisms used in electrical systems.

CO2 :Design inductors for power electronic and electrical applications.

CO3 :Design power transformers and high-frequency transformers considering electrical, thermal, and magnetic constraints.

CO4 :Explain the structure and design considerations of solid-state transformers.

Magnetic Materials and Fundamentals of Magnetic Design

Magnetic circuit concepts- Magnetic materials and their properties- B H characteristics- Core losses- including hysteresis and eddy current losses- Soft magnetic materials- Laminated steel cores- Ferrites and amorphous cores- Selection of core materials for low- frequency and high-frequency applications- Thermal considerations in magnetic components- Introduction to electromagnetic interference in magnetic components.

Design of Inductors for Electrical and Power Electronic Systems

Types of inductors- Air core and magnetic core inductors- Energy storage in inductors- Inductor design equations- Core selection and air gap design- Saturation effects- Winding design and current density- Copper losses and core losses- Thermal considerations- Design examples of inductors used in DC-DC converters and filter applications.

Design of Power Transformers and High Frequency Transformers

Power transformer design principles- Transformer ratings- Core and winding design- Insulation requirements- Losses and efficiency- Cooling methods- Introduction to transformer standards- High-frequency transformer design- Differences between power frequency and high frequency transformers- Ferrite cores- Skin effect and proximity effect- Winding techniques- Leakage inductance and parasitic capacitance- Transformer design for switched-mode power supply applications.

Design of Solid-State Transformers

Introduction to solid-state transformers- Comparison with conventional transformers- Role of power electronics and high-frequency magnetic components- Multi-stage solid-state transformer architecture-High-frequency isolation transformer design- Insulation and thermal considerations- Applications in smart grids, renewable energy systems, and electric vehicles- Design challenges and future trends.

References

1. Scott D. Sudhoff, Power Magnetic Devices: A Multi-Objective Design Approach, Wiley , 2014.
2. McLyman C W T, Transformer and Inductor Design Handbook, CRC Press, 2004.
3. Erickson R W and Maksimovic D, Fundamentals of Power Electronics, Springer, 2020.
4. Hurley W G and Wolfle W H, Transformers and Inductors for Power Electronics, Wiley, 2013..

EE6531E CONDITION MONITORING OF POWER ELECTRONIC CONVERTERS

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

- CO1: Understand various failure mechanisms of power semiconductors.
CO2: Explain about condition monitoring of different power semiconductor devices.
CO3: Understand the failure mechanisms of capacitors.
CO4: Conduct reliability analysis of power electronic conversion systems.

Failure Mechanisms in Semiconductor Devices

Failure Mechanisms of Power Semiconductors: Aluminum reconstruction Bond fatigue, Die-attach fatigue and delamination Substrate cracking Bond-wire melting, Die-attach voiding, Aluminum corrosion, Latchup, Avalanche breakdown, Partial discharge Electrochemical and silver migration, Dielectric breakdown, Time-dependent dielectric breakdown, Hot carrier injection, Competing failure mechanisms.

Diagnostic Methods for IGBTs

IGBT failure- wear out/catastrophic, Thermal modeling of IGBT-analytic, numeric, and network models, Modeling of GaN devices for break down voltage assessment, IGBT Failure Mechanisms, On-state voltage drop monitoring for aging detection, Vibration and acoustic emission monitoring for mechanical integrity, High-temperature operation effects on GaN devices.

Diagnostic Methods for Capacitors

Condition Monitoring of Capacitors in PEC System: Capacitors for DClinks in power electronic converters, Failure mechanisms and lifetime models of capacitors, Reliability-oriented design for DC links, Aging detection for capacitors, Condition monitoring of DC-link capacitors.

Life Prediction of Power Electronic Devices

Anomaly detection and remaining life prediction for power electronics-failure models, Data driven methods for life prediction , Reliability Analysis and Data-Driven Condition Monitoring of PEC

References:

1. H. S. Chung, H. Wang, et al., Reliability of Power Electronic Converter Systems, IET, London, 2015.
2. A. Haque, et al., Reliability of Power Electronic Converter for Solar PV Applications, IET, London, 2016.
3. Jun Wang et al, Reliability of Power Electronics Devices and Converter Systems, MDPI, 2025

EE6532E EXTRA HIGH VOLTAGE AC POWER TRANSMISSION

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

- CO1: Analyse the need of EHV and UHV systems.
CO2: Estimate the electric field from EHV lines.
CO3: Understand the different types of substation earthing schemes
CO4: Understand the design of a GIS and GIL

Electrical Power Transmission at High Voltages:

Overview of Electrical power transmission at high voltages. Overhead transmission lines: Bundled conductors, Resistance, Inductance and capacitance calculations of EHV line and multiconductor configurations-sequence inductance and capacitance-line parameters for modes of propagation- Temperature rise of conductors and current carrying capacity.

Surface voltage gradient and its interference issues:

Computation of surface voltage gradient on conductors, Corona: Power loss due to corona, Radio noise and Audible noise and their measurement as well as computation. Electric Field under transmission lines and its computation Effect of ES fields of humans, Animals and plants.

Substation grounding and Shielding:

Functional Requirements of Earthing System, Equipment Earthing, Neutral Point Earthing, Substation Earthing System, Dimensioning of Earth Conductors, Step Potential and Touch Potential, Earth Mat, Resistance of Earthing System, Values of Soil Resistivity, Fencing, Procedure of Laying Earthing, Shielding by wires and masts.

Gas Insulated Substation:

Evolution of GIS, Basics of GIS technology, Key design features, SF6 volume reduction, Reliability of GIS, Design tests, Gas tightness and monitoring, Global status of GIS. Gas Insulated Transmission Line: Why GIL, Historical development of GIL, Applications of GIL, Basic units of GIL, Basic insulation level and current carrying capacity of GIL, Gas mixture as insulation, Installation of GIL, Comparison of GIL with cables and overhead lines, sustainability aspect of various gases used.

References

1. Hermann Koch, *Gas Insulated Substations*, Wiley, 2014.
2. R.D. Begamudre, *EHV AC transmission engineering*, New age international, 2006.
3. Kimbark E.W., *HVDC transmission*, Wiley, 1965.
4. Arrilaga J, *High voltage Direct Current Transmission*, Peter Peregrinus, London, 2007

EE6201E COMPUTER METHODS IN POWER SYSTEM ANALYSIS

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	1	0	5	3

Course Outcomes:

CO1: Formulate network admittance and impedance matrix for various analyses of power systems

CO2: Execute load flow and short circuit analysis on large scale AC, DC and AC-DC power systems using digital techniques.

CO3: Choose appropriate load flow methods on various distribution systems

CO4: Develop mathematical models for State Estimation and Contingency analysis

CO5: Assess the various security measures taken for operation of power system

Network Modelling

Network modelling - System Graph. Loop, Cutset and Incidence Matrices - Y Bus Formation – Mutually coupled branches in Y Bus - solution techniques for linear networks -Gaussian Elimination, LU Factorization, Network reduction techniques - Sparsity programming and Optimal Ordering - [ZBUS] Building Algorithm with Mutually coupled branches – digital simulation.

Load Flow Studies and Fault Analysis

Power Flow Analysis: Review of Gauss-Seidel, Newton-Raphson, Decoupled and Fast Decoupled Methods, DC Power Flow, AC-DC Load Flow Analysis, Load Flow under Power Electronic Control

Fault Analysis: Review of Sequence Matrices- Review of Symmetrical and Unsymmetrical Short-Circuit Analysis of Large Power Systems - Phase Shift in Sequence Quantities Due to Transformers - digital simulation

Distribution System Analysis

Load flow analysis of balanced and unbalanced radial distribution system – Load flow analysis of weakly meshed system – Backward/forward sweep - Direct approach - Direct approach for weakly meshed systems - Gauss Implicit Z-matrix Method - Short-circuit analysis: Sequence-components vs. phase-variable - LG, LLG, LLLG, and LL Faults – Weakly meshed system - Applications of distribution system analysis Power System Security and State Estimation Power system security - Contingency analysis - adding and removing multiple lines, Analysis of single and multiple contingencies, Contingency Analysis by DC model, System reduction for contingency and fault studies – linear sensitivity factors – AC power flow methods – contingency selection – concentric relaxation – bounding-security constrained optimal power flow-Interior point algorithm-Bus incremental costs.

State estimation – least square and weighted least square estimation methods for linear and non-linear systems. Static state estimation of power systems- injections only and line only algorithms, Treatment of bad data – detection, identification and suppression of bad data.

References:

1. John J. Grainger and William D. Stevenson, *Power System Analysis*, Tata McGraw-Hill, 2003
2. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
3. George L. Kusic, *Computer Aided Power System Analysis*, Prentice Hall of India (P) Ltd., New Delhi, 1989.
4. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer modelling of Electric Power Systems*, Wiley, New York, 1983.
5. A.K. Mahajanabis, D.P. Kothari, S.I. Ahson, *Computer Aided Power System Analysis & Control*, Tata McGraw Hill, New Delhi, 1988.
6. O.I. Elgard, *Electric Energy System Theory: An Introduction*, 2nd ed., McGraw Hill, New York, 1982.
7. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
8. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.
9. Allen J. Wood, Bruce Wollenberg and Gerald B. Sheble, '*Power Generation, Operation and Control*', 3rd Edition. John Wiley and Sons, 2013

EE6202E POWER CONVERTERS FOR POWER SYSTEM APPLICATIONS

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	1	0	5	3

Course Outcomes:

CO1: Understand various VSC Topologies used in various Power System applications of Power Electronic Converters

CO2: Appraise the operation and performance of Two-Level Single phase and Three phase VSCs under various modulation schemes.

CO3: Describe the operation of various multi pulse VSCs, three-level NPC VSCs and Cascaded H Bridge VSCs that are routinely employed in Power System Applications.

CO4: Develop the capability to model VSC based systems in $\alpha\beta$ - frame and dq -frame for designing control systems for them.

CO5: Understand different operational and design aspects of controllers for controlling a grid-connected VSC System in $\alpha\beta$ -frame and dq -frame for meeting different control objectives.

Introduction

Power Electronic Converters & Converter Systems : PE Switches – Switch Classification, Switch Characteristics, Classification of Converters – based on commutation process, based on terminal voltage & waveforms, Voltage-Sourced Converters (VSC) – Basic configurations. Brief Survey of applications of VSCs in Power Systems : STATCOM, DSTATCOM, SSSC, DVR, PQC, UPFC, Active Filters, VSC-based HVDC, Renewable Energy Grid Interface etc., Self-sustained DC Bus versus Active DC Bus in Power System Applications of VSC, Two Basic Strategies for Control of AC Side and DC Side in VSC-Based Power System Applications – Synchronous Link Power Control Principles, Current Regulation in VSCs.

Advanced VSC Configurations : Multimodule VSC, Multipulse VSC, Multilevel VSC, Modular Multilevel VSC

Two-Level VSC Modulation Schemes

Single Phase Two-Level VSC : Half-bridge and Full-bridge Single Phase VSC with square wave switching, Harmonic performance, Sinusoidal Pulse Width Modulation (SPWM) for Single Phase half-bridge and full-bridge VSC, Bipolar versus Unipolar SPWM, Harmonics and filtering, Leakage current issue in SPWM Single Phase Inverters fed from Solar Panels, The H5 Inverter for Photovoltaic application

Three Phase Two-Level VSC : 180° and 120° square wave operation of basic 6-pulse three-phase Inverter - Analysis of waveforms for 180° mode with R-Load and RL-Load, Programmed Harmonic Elimination (PHE) for 2-Level three-phase VSC – Implementation of PHE, SPWM for 2-Level three-phase VSC – harmonics; choice of carrier frequency; DC Voltage utilisation; third harmonic injection ; filtering requirements

Space Vector Modulation (SVM) : Motivation for SVM for Three-phase Two-Level VSC, Switching States, Space Vectors, Dwell Time calculation, Modulation Index, Switching Sequence, Spectrum Analysis, Even Harmonic Elimination, Discontinuous SVM. Introduction to Current Regulated Two-Level VSC: Application of Current-regulated VSCs in Power Systems – Grid side current regulation in a grid-connected single-phase two-level PWM inverter by hysteresis control – Hysteresis current control in grid-connected three-phase two-level PWM Inverter – Disadvantages of hysteresis current control

Advanced VSC Configurations

Multipulse VSCs : Harmonics in 6-pulse VSC, 12-pulse VSC arrangement and magnetic involved, harmonic performance of 12-pulse VSC, 24-pulse VSC arrangement and magnetic involved, harmonic performance of 24-pulse VSC, 48-pulse VSC arrangement and magnetic involved, harmonic performance of 48-pulse VSC, Combining PHE and Multipulsing – motivation, implementation aspects.

Diode Clamped Multilevel Inverters : Three Level Single Phase Half Bridge Neutral Point Clamped (NPC) VSC, PWM Scheme for Half Bridge NPC - Harmonic performance, Three Level NPC Three Phase VSC with impressed DC Voltages, NPC VSC with Capacitive DC Side Voltage Divider – Partial DC Side Voltage drift; DC Side Voltage Equalisation; DC Side Currents Space Vector Modulation for NPC VSC

Cascaded H Bridge Inverters : CHB Inverter with equal DC voltages, CHB Inverter with unequal DC voltages, Carrier based PWM Schemes – Phase shifted Multicarrier Modulation; Level shifted Multicarrier Modulation; comparison, Staircase Modulation

Modelling & Control of Grid-Connected VSC.

Half-bridge PWM VSC Modelling & Control : Switched Model, Averaged Model, Non-ideal Converter, Averaged Model for Non-ideal Converter, AC Side Control model of Half-bridge converter, Control of Half-bridge converter, Feedforward compensation and its impact, Sinusoidal Command Following

Space Phasors & Two dimensional Frames : Space Phasor – definition; changing amplitude and phase of a three-phase signal; generating a controllable amplitude controllable frequency three-phase signal, $\alpha\beta$ -frame – $\alpha\beta$ representation of a space phasor; realization of signal generators and signal conditioners in $\alpha\beta$ frame; power in $\alpha\beta$ -frame; control in $\alpha\beta$ -frame; representation of systems in $\alpha\beta$ -frame, dq-frame – dq representation of a space phasor; realization of signal generators and signal conditioners in dq frame; power in dq-frame; control in dq-frame; representation of systems in dq-frame, Averaged Model of a two-level VSC, Model of a two-level VSC in $\alpha\beta$ -frame, Model of a two-level VSC in dq-frame

Control of Grid-Imposed Frequency VSC in $\alpha\beta$ -frame : Structure of grid-imposed frequency VSC System, Real/Reactive Power Control – Current-mode versus Voltage-mode control; Model of Real/Reactive Power Controller $\alpha\beta$ -frame ; Current-mode Control Real/Reactive Power in $\alpha\beta$ -frame; Selection of DC Bus Voltage Level, Controlled DC Voltage Power Port – Model of Controlled DC Voltage Power Port in $\alpha\beta$ -frame; DC Bus Voltage Control in $\alpha\beta$ -frame.

Control of Grid-Imposed Frequency VSC in dq-frame : Dynamic Model of Real/Reactive Power Controller dq-frame ; PLL and Compensator for PLL; Current-mode Control Real/Reactive Power in dq-frame; Selection of DC Bus Voltage Level; AC Side equivalent circuit, Controlled DC Voltage Power Port – Model of Controlled DC Voltage Power Port in dq-frame; DC Bus Voltage Control in dq-frame.

References:

1. Amirnaser Yazdani & Reza Iravani, *Voltage-Sourced Converters in Power Systems*, IEEE Press, John Wiley & Sons, 2010.
2. Bin Wu, *High Power Converters and AC Drives*, IEEE Press, John Wiley & Sons, 2006.
3. Remus Teodorescu, Marco Liserre & Pedro Roderiguez, *Grid Converters for Photovoltaic and Wind Power Systems*, IEEE Press, John Wiley & Sons, 2011.
4. Narain G. Hingorani & Laszlo Gyugyi, *Understanding FACTS*, IEEE Press, 2000.
5. Ned Mohan, William P. Robbins & Tom M. Undeland , *Power Electronics*, John Wiley & Sons.
6. Muhammad H. Rashid, *Power Electronics*, Third Edition, Pearson Education, 2004.

EE6204E SIGNAL PROCESSING FOR POWER SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: **39**

Course Outcomes:

CO1: Evaluate applications of Digital signal filtering techniques in power systems

CO2: Apply estimation techniques to evaluate power system parameters

CO3: Analyse different signal decomposition techniques

CO4: Evaluate the WAMS signal processing

Power Systems signals in terms of Smart Grid

Need for Signal Processing in Basics of power quality issues, Inrush Current in Power Transformers; Over-Excitation of Transformers; Transients in Instrument Transformers; Frequency Variation; Voltage Magnitude Variations; Voltage Frequency Variations, power system protection, Wide area dynamic analysis Power Systems and signal processing. Stochastic gradient based algorithms – LMS algorithm, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Mean-squared error behaviour, Convergence analysis, Prediction, filtering and smoothing, adaptive equalization, noise cancellation, blind deconvolution, adaptive IIR filters, RLS algorithms- GRLS, Gauss-Newton and RM. Basic Digital System, Parametric Notch FIR Filters; Sine and Cosine FIR Filters, Parametric Filters applications in smart grid,

Filters and Electrical Parameters Estimation

Forward and backward linear prediction, prediction error filters, AR lattice and ARMA Lattice – Ladder filters, Kalman filters, Wiener filter, Least Square methods for system modelling & Filter Design. Recursive least squares algorithms, Matrix inversion lemma, Spectrum estimation. Estimation of autocorrelation. Periodogram, Nonparametric and Parametric methods. Estimation Theory; Least-Squares Estimator; Frequency Estimation; Phasor Estimation; Phasor Estimation in Presence of DC Component; Spectrum Estimation; Windows; Frequency-Domain Windowing; Interpolation in Frequency Domain: Multitoned Signal.

Time-Frequency Signal Decomposition

Short-Time Fourier Transform; Sliding Window DFT; Filter Banks; Pattern Recognition, Feature Extraction on the Power Signal; Signal Detection for Electric Power Systems; Detection Theory. Concepts of wavelet, s-transform, heartly s-transforms; Hillbert transform; Gabor transform and applications in power fluctuations: load fluctuations, wind farm power fluctuations and smart microgrid, Asset Management.

References

1. J.G.Proakis, M. Salehi, *Advanced Digital Signal Processing*, McGraw –Hill, 1992.
2. Paulo Fernando Ribeiro, Carlos Augusto Duque, Paulo Marcio da Silveira, Augusto Santiago Cerqueira, *Power Systems Signal Processing for Smart Grids*, John Wiley and Sons Ltd, 2014
3. Lizhe Tan Jean Jiang., *Digital Signal Processing Fundamentals and Applications [3rd Edition]*, Academic Press, 2018
4. Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski, *Digital Signal Processing in Power System Protection and Control*, Springer-Verlag London Limited, 2011
5. CIGRE WG C4.07 (October, 2004) *Power quality indices and objectives*. Technical Report No 261. CIGRE/CIRE Working Group C4.07, Power Quality Indices and Objectives, CIGRE Technical Brochure 261, Paris.
6. Bollen, M.H.J. (2000) *Understanding Power Quality Problems: Voltage Sags and Interruptions*, Wiley–IEEE Press.
7. Mitra, S.K, *Digital Signal Processing: A Computer Approach*, McGraw–Hill Companies, Inc.2006. IEC61869 1-9 (2007 to 2012)
8. *Instrument transformers: additional requirements*. International Electrotechnical Commission, Geneva, Switzerland.
9. Hamming, R. *Digital Filters*, Dover,1998.
10. Vaidyanathan, P.P, *Multirate Systems and Filter Banks*, Prentice Hall, Englewood Cliffs, New Jersey. 1993.
11. Sodney Burrus, C., Gopinath, R.A. and Guo, H. *Introduction to Wavelets and Wavelet Transforms: A Primer*, Prentice Hall, New Jersey. 1998
12. Bollen, M.H.J. and Gu, I.Y.H. *Signal Processing of Power Quality Disturbances*, IEEE Press and Wiley Interscience, NJ. 2006

EE6213E DIGITAL PROTECTION OF POWER SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: **39**

Course Outcomes:

CO1: Explain various digital protective schemes for transmission lines and power apparatus.

CO2: Select and design instrument transformers for a specific protection scheme design.

CO3: Realise numerical relays in hardware platform.

CO4: Conduct testing and coordination of relays.

Art of relaying

Protective Relaying - Qualities of relaying - Definitions - Codes- Standards; Characteristic Functions; Classification – analog - digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection.

Digital Relaying

Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms travelling

wave protection schemes; Relay Schematics and Analysis Over Current Relay-Instantaneous/Inverse Time –

IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types Characteristics. Relay coordination- Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples

Apparatus and System protection

Digital Protection of power system apparatus – protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection.

Bus bar protection - line protection - distance protection–long EHV line protection - Power line carrier protection

Motor Protection

Pilot wire and Carrier Current Schemes; Reactor protection – Protection of boosters - capacitors in an interconnected power system. System grounding –ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Reclosing and synchronizing.

Advanced Protection Schemes

Integrated and multifunction protection schemes -SCADA based protection systems- Fault Tree Analysis; Testing of Relays- Field test procedures for protective relays. Adaptive relaying- AI & Fuzzy Based Protection, Intelligent Transmission Line Relaying Fault Detection.

References:

1. A.G.Phadke, James S.Thorp, '*Computer Relaying for Power Systems*', 2nd EJohn-Wiley and sons, 2009.
2. Waldemar Rebizant , Janusz Szafran, and Andrzej Wiszniewski. "*Digital Signal Processing in Power System Protection and Control*", Springer Publication, 2011.
3. A.T.Johns and S.K.Salman, '*Digital Protection for Power Systems*' , IEEE Power Series, 1997
4. Stanley H. Horowitz, Arun G. Phadke, and Charles F. Henville. '*Power System Relaying*', 5th Edition, John Wiley & Sons 2022
5. D N Vishwakarma, Badri Ram, and Soumya R Mohanty. '*Power System Protection and Switchgear*', 3rd Edition. McGraw Hill, 2022
6. Latest IEEE Transactions papers on recent advancements in digital and adaptive relays
7. Latest Digital relay manuals of ABB, Siemens etc.

EE6214E POWER SYSTEM ECONOMICS AND DEREGULATION

Pre-requisite: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: **39**

Course Outcomes

CO1: Understand the principle and operation of deregulated power system.

CO2: Illustrate how electricity is priced in deregulated power markets.

CO3: Explain the working of various electricity markets around the world.

CO4: Understand the economics and business opportunities of utilities and end-consumers.

Introduction to Deregulation

Why deregulate? – What to deregulate – Pricing power, energy, and capacity - Power supply and demand – Market structure and architecture – Spot market – Day ahead market – Real time market – Reserve market – Ancillary services - US and European market evolution - Reforms in Indian power sector Energy and Derivative Markets Concept of marginal cost - Market equilibrium – Market clearing price – Congestion pricing fundamentals – Locational marginal pricing – Operating reserve pricing – Value-of-lost-load pricing – Pricing losses on lines - Pricing losses at nodes - Derivative markets – Hedging risk – Contract for difference - Forwards - Futures – Options – Swaps

Power Generation Economics

Cost of Power Generation – Levelized Cost of Energy – Generation Planning – Investment Analysis– Time Value of Money – Net Present Value – Benefit/cost Ratio – Payback Period - Profit/investment Ratio – Business Economic Feasibility Study – Power Purchase Agreements

Distribution System and Microgrid Economics

Tariff and Energy Bills – Net Metering – Net Feed-in - Rooftop Solar PV Business models - Customer Savings Analysis – Grid Parity – Utility and DSO economics - Local energy markets – Virtual power plant and microgrids – Microgrid prosumer consortium – Role of DSO – Business models

References:

1. Daniel S. Kirschen, Goran Strbac, 'Fundamentals of Power System Economics, Wiley, 2018.
2. Darryl R. Biggar, Mohammad Reza Hesamzadeh, 'Economics of Electricity Markets', Wiley-IEEE press, 2014.
3. Mohammad Shahidehpour, Muwaffaq Alomoush, 'Restructured Electrical Power Systems: Operation: Trading, and Volatility', Marcel Dekker Inc., 2001.
4. Steven Stoft, 'Power System Economics: Designing Markets for Electricity', Wiley-IEEE Press, May 2002.
5. Anna Creti, Fulvio Fontini, 'Economics of Electricity', Cambridge University Press, May 2019.
6. Loi Lei Lai, 'Power System Restructuring and Deregulation', Wiley, 2001.
7. Jin Zhong, 'Power System Economic and Market Operations', CRC Press, 2018.
8. Kankar Bhattacharya, Math H. J. Bollen, Jaap E. Daalder, 'Operation of Restructured Power System', Springer, 2001.

EE6226E DISTRIBUTED GENERATION AND MICROGRIDS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the concept of distributed generation and technologies.

CO2: Investigate the technical challenges of Distributed Generation technologies.

CO3: Design the microgrid architectures and its control operation.

CO4: Explore smartgrid technologies and infrastructure.

Renewable Integration to Grid

Modern Power System: Generation - Transmission - Distribution - Loads - Introduction to Distributed Generation (DG) - Technologies of DG - IEEE 1547- Solar photovoltaic generation - wind energy - Wind power plants - Microturbines - Fuel Cell - Storage Systems - batteries, fly-wheels, ultracapacitors - unit sizing of DGs - Case studies.

Distributed Energy Sources

Penetration of DGs Units in Power Systems - Integration of DGs Units in Distribution Network -Modern Power Electronics for DGs Applications – multiple and single input dc-dc converters - ac-dc and dc-ac converters – Technical restrictions - Protection of DGs - Economics of DGs –Pricing and Financing framework for DG units – Optimal placement of DGs - Case studies.

Microgrid

Introduction to Microgrids - AC and DC microgrids - Operational Framework of Microgrids - anti-islanding schemes - Distribution Management System (DMS) - Microgrid System Central Controller (MGCC) - Local Controllers (LC) - Economic, environmental and operational benefits of Microgrids in a distribution network - Demand Response Management in Microgrids - Business Models and Pricing Mechanism in Microgrids - Interconnection of Microgrids.

Smart Grid

Introduction to Smart Grids (SG) - Factors affecting the growth of SG - The global reality in the field of smart grids and transition into future grids - Smart Agents - Electronics and communications infrastructure in SG - ICT Technologies - smart meters - metering infrastructures - metering equipment - communication of metering equipment - communication protocols - Metering Data Management Systems (MDMS) - Application of SGs - Interconnections issues between SGs

References:

1. N. Hatziaargyriou, *Microgrids: Architectures and Control*, Wiley-IEEE Press, 1st Edition, 2014
2. J. N. Twidell & A. D. Weir, *Renewable Energy Sources*, University press, Cambridge, 2001
3. James Larminie , Andrew Dicks , *Fuel Cell Systems*, John Wiley & Sons Ltd, 2000
4. J. F. Manwell , J. G. McGowan, A. L. Rogers , *Wind Energy Explained*, John Wiley & Sons Ltd 2009
5. Loi Lei Lai, Tze Fun Chan, *Distributed Generation- Induction and Permanent Magnet Generators*, IEEE Press, John Wiley & Sons, Ltd., England. 2007.
6. Amirnaser Yezdani, and Reza Iravani, *Voltage Source Converters in Power Systems: Modeling, Control and Applications*, IEEE John Wiley Publications, 2009

EE6228E DATA ANALYTICS IN POWER SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the concepts of data analytics in power systems.

CO2: Apply various machine learning and classifier algorithms to big data applications in power systems.

CO3: Analyse various techniques in data security in Smart Grid Communications

CO4: Apply various Optimization methods in data analytics

CO5: Apply the data analytics in power system operation, control and protection paradigms

Data in Power Systems

Introduction: Big Data-Future Power Systems-Big Data Application and Analytics in a Large-Scale Power System- Role of Big Data Analytics in Smart Grid Communications-Big Data Optimization in Electric Power Systems: A Review - Security Methods for Critical Infrastructure Communications- Data Mining Methods for Electricity Theft Detection – Unit Commitment Control of Smart Grids - Data-Based Transformer Differential Protection

Big Data Application in Large-Scale Power System

Big Data Application and Analytics in a Large-Scale Power System: General Applications of Big Data-Health Care-Social Networking-Handling Big Data. Algorithms for Processing Big Data-Machine Learning and Deep Learning Generalities. Machine Learning- Artificial Neural Network (ANN) Model-Support Vector Machine (SVM)- Decision-Tree Classifier. Deep Learning-Deep Learning Models-Challenges and Suggested Solutions for Using Deep Learning in Big Data Analytics. Application of Big Data in Power Systems-Big Data in Smart Grid Networks-Phasor Measurement Units (PMU)- Renewable Energy-CIM as Information Standard for Big Data Analytics-Big Data Problem in Power System Modeling-Security-Constrained Unit Commitment (SCUC)- Decomposition Methods to Handle Big Data-Firm Transmission Right (FTR) Problems-Time-Constrained Economic Dispatch.

Big Data security in Smart Grid Communications

Role of Big Data in Smart Grid Communications: Grid Modernization-Grid Interconnection with the Internet of Things- Data Traffic Pattern in a Smart Grid Environment-Phasor Measurement Unites Applied to Distribution Systems-Advanced Metering Infrastructure (AMI)- Massive Flow of Information in a Smart Scenario-Volume of Generated Data in a Smart Distribution System: Case Studies-Generated Data by PMUs-Generated Data by Metering Infrastructure - Data Mining Methods for Electricity Theft Detection: Introduction-Transmission and Distribution System Losses-Electricity Theft Methods-Fraud-Bypassing Existing Meetings-Meter Tampering-Billing Issues-Outright Theft-Electricity Theft and Data Collection-Data Mining and Electricity Theft-Prediction-Classification and Clustering-Issues and Directions in Electricity Theft-Related Data-Mining Research.

Big Data Optimization in Electric Power Systems

Big Data Optimization in Electric Power Systems: Background-Scientometric Analysis of Big Data-Big Data and Power Systems-Big Data Optimization-Application of Big Data in Power System Studies. Optimization Techniques Used in the Big Data Analysis-Computational Method for Large-scale Unconstrained Optimization - Numerical Approach for Non-smooth Large-scale Optimization-Big Data in Logistics Optimization-Big Data Analytics Based on Convex and Nonconvex Optimization-Metaheuristic Algorithms for Big Data Optimization.

Data in Control and Protection

Multi-agent Architecture-Smart Grid Using Multi-Agent Model-Agent's Profile-Decision-Making Method-Storing and Selling Extra Power Procedure-Examples Protection Algorithm Based on Data Pattern Recognition: Big Data and Power System Protection-Methods for Differential Protection Blocking - Harmonic Restraint and Harmonic Blocking-Methods Based on Waveform Recognition - Principal Component Analysis-Curvilinear Component Analysis (CCA)-PCA Applied to Discriminate Between Inrush and Fault Currents in Transformers- Application of the CCA as a Base for a Differential Protection

References

1. Ahmed F. Zobaa and Trevor J. Bihl [Edited], *Big Data Analytics in Future Power Systems*, CRC Press,Taylor & Francis Group, 2019
2. Reza Arghandeh and Yuxun Zhou [Edited], *Big Data Application in Power Systems*, Elsevier, 2018
3. Robert C. Qiu and Paul Antonik, *Smart Grid using Big Data Analytics: A Random Matrix Theory Approach*, John Wiley & Sons Ltd, 2017
4. Patrick C. K. Hung [Edited],*Big Data Applications and Use Cases*, Springer International Publishing Switzerland 2016

EE6303E MODERN DIGITAL SIGNAL PROCESSORS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: **39**

Course Outcomes:

CO1: Understand and analyse the architecture of digital signal processors.

CO2: Design a digital system using digital signal processors

CO3: Program various DSP processors using IDEs.

CO4: Choose and utilize modern digital signal processors for power electronic applications.

Introduction to Digital Signal Processors (DSP)

Types of digital processors- microprocessor, microcontroller, digital signal processors/controllers, differences in architecture, features, peripherals and functionality, Memory hierarchy, types of memory, memory map, Instruction set.

Modern trends in DSP: Von Newmann versus Harvard architecture, fixed- and floating-point processors, New Digital Signal Processing hardware trends, Selection of DS processors.

Internal details of DSP using Texas Instruments DSP (TMS320C6000 Series) as a tool: DSP Architecture, CPU Data Paths and Control, Internal Data/Program Memory. On chip peripherals and its programming details: Timers - Multi channel buffered serial ports - Extended Direct Memory Access, Interrupts, Pipelining.

Programming the DSP

Texas Instruments IDE - CC Studio - Introduction to the C6713 DSK- Review of FIR filtering: FIR filter design techniques and tools, Review of IIR filtering: IIR filter design techniques and tools, Sampling, quantization and working with the AIC23 codec, Writing efficient code: optimizing compiler - effect of data types and memory map. TMS320C6713 Assembly language Programming: Instructions Set and Addressing Modes – Linear Assembly. Interfacing CC Studio with MATLAB.

Current Trend in Digital Signal Processors

Converter and Motor Control Digital Signal Processing Solutions Using the TMS320F240DSP-Controller. Architecture of TMS320C2XX series DSP and its applications. Architecture trends of other DSP processors, Analog Devices DS processors: ADSP-2105 digital signal processor for motor control applications, Microchip dsPIC controllers for power electronics applications. Other major vendors in the DSP market and the latest trends.

References:

1. On-line TI materials for the TI C6713 DSK board: <http://www.ti.com>
2. Naim Dahnoun, *Digital Signal Processing Implementation using the TMS320C6000 DSP Platform*, 1st Edition.
3. R. Chassaing, *Digital Signal Processing and Applications with the C6713 and C6416 DSK*, John Wiley and Sons, Inc., New York, 2004
4. Sen M. Kuo and Woon-Seng Gan., *Digital Signal Processors: Architectures, Implementations, and Applications*, Pearson, 2005.
5. David J Defatta J, Lucas Joseph G & Hodkiss William S, *Digital Signal Processing: A System Design Approach*, 1st Edition; John Wiley, 2009.
6. A.V. Oppenheim and R.W. Schafer, *Discrete-Time Signal Processing*, Third Edition, Pearson, 2014.
7. John G Proakis, Dimitris G Manolakis, *Digital Signal Processing*, Pearson, 2006.
8. On-line Microchip materials: <http://www.microchip.com/design-centers/intelligent-power>

EE6323E DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: **39**

Course Outcomes:

CO1: Develop mathematical model of power electronic switches and electrical machines.

CO2: Model and simulate Power Electronic Systems using software packages such as PSpice, MATLAB-Simulink & Saber

CO3: Design and simulate power electronic systems using PSpice.

CO4: Illustrate power electronic system design and simulation using MATLAB-Simulink.

CO5: Analyse and design power electronic systems and simulate using Saber.

Principles of Modelling Power Semiconductor Devices

Macro models versus Micro models– Semiconductor device models - Semiconductor Device modelled as Resistance, Resistance-Inductance and Inductance-Resistance-Capacitance combination - Modelling of Electrical Machines - Modelling of Control Circuits for Power Electronic Switches. Computer Formulation of Equations of Power Electronic Systems - Review of Graph Theory as applied to Electrical Networks - Systematic method of Formulating State. Equations – Computer Solution of State Equations - Explicit Integration method - Implicit Integration method.

Simulation with MATLAB

Overview of MATLAB Workspace, Simulink and Simscape- Writing a code in MATLAB Editor- Various solvers and simulation step size in simulations- Circuit simulation of a power converter using Simulink- Model based simulation of a power converter system using Simulink-Coding the MATLAB function block.

Simulation with PSpice

Circuit Analysis Software MicroSim PSpice A/D - Simulation Overview - Creating and Preparing a Circuit for Simulation - Simulating a Circuit with PSpice A/D - Displaying Simulation Results - PSpice A/D Analyses-Simple Multi-run Analyses - Statistical Analyses - Simulation Examples of Power Electronic systems.

Simulation with Saber

Design Creation and Simulation with Saber Designer - Placing the Parts - Editing the Symbol – Properties -Wiring the Schematic - Modifying Wire Attributes - Performing a Transient and DC Analysis – Placing Probes in the Design - Performing AC Analysis and Invoking Saber Scope - Analysing waveforms with Saber Scope - Performing Measurements on a waveform - Varying a Parameter - Displaying the Parameter Sweep Results - Measuring a Multi-Member Waveform - Simulation Examples of Power Electronic Systems.

References:

1. V.Rajagopalan, *Computer Aided Analysis of Power Electronic Systems*, Marcel Dekker, Inc,1987.
2. *Micro Sim PSpice A/D and Basics+: Circuit Analysis Software*, User's Guide, Micro Sim Corporation
3. *Micro Sim Schematics: Schematic Capture Software*, User's Guide, Micro Sim Corporation.
4. Farzin Asadi, *Simulation of Power Electronics Circuits with MATLAB/Simulink: Design, Analyze, and Prototype Power Electronics*, Apress, 2022.
5. *Getting Started with Saber Designer (Release 5.1)*, An Analogy Inc.

EE6327E COMPUTER AIDED DESIGN OF ELECTROMAGNETIC SYSTEMS

Pre-requisites: Fundamental knowledge of electric machine analysis

L	T	P	O	C
2	0	2	5	3

Total Sessions: **26L + 26P**

Course Outcomes:

CO1: Understand the basic functioning of the ANSYS user interface

CO2: Choose the simulation settings necessary for a particular problem

CO3: Design and analyse single phase and three phase transformers on FEM platform

CO4: Design and analyse squirrel cage induction machine on Rmxprt and Motor CAD

Introduction to ANSYS Maxwell Interface

Maxwell desktop interface - Maxwell 2-D and 3-D simulation - Graphics and view settings for 2-D and 3-D simulation - Types of simulation - Magnetostatic and transient simulation - Eddy current simulation - Basic drawing and geometry operation - Material assignment - Force, torque and matrix calculation - Virtual and lorentz force - Magnetostatic and transient solution of a rotational actuator - Transient simulation of 2-D rotational actuator.

Mesh, Boundary, Excitation and Motion Settings

Mesh settings - Length based mesh, Element based mesh, Surface approximation, Skin depth based mesh, Trade off between mesh density and solution accuracy. Boundary settings - Vector potential, Balloon, Odd and even symmetry, Independent and dependent boundaries, Master and slave boundaries, Excitation settings - Assigning coil terminals, Voltage excitation, Current excitation, External circuit, Integrating external circuit with magnetic geometry. Motion settings - Translational motion, Rotational motion, Non cylindrical rotational motion, Limits of motion, Constant speed operation, Mechanical transient and load torque, Band setting.

Design of Single Phase and Three Phase Transformers

Plotting flux paths for a bar electromagnet - Simulation of rectangular core inductor for dc and ac excitation - Plots of time varying inductance and induced emf - Comparison of 2-D and 3-D simulation of a core type single phase transformer - Open circuit and short circuit test - 3-D simulation of three phase core type transformer - Calculation of core loss and copper loss for three phase transformer.

Analysis of Induction Machine Using Rmxprt

Introduction to Rmxprt interface - Squirrel cage induction machine prototype - Constant torque and constant power simulation - Rmxprt to Maxwell transport - Flux density distribution along line and surface - Plotting torque speed characteristics - Exporting FEM data to MATLAB - Determination of equivalent circuit parameters.

Motor CAD Assisted Design of Induction Machine

Introduction to Motor CAD user interface - Standard templates for available electrical machines - Basic electromagnetic simulation - Line fed induction machine - Inverter fed induction machine - Basic thermal analysis - Transfer of data from Motor CAD to MATLAB - Transfer of data from Motor CAD to ANSYS

Practical Sessions:

List of Experiments

- 1) Calculation of torque developed in a rotational actuator using magnetostatic analysis on Maxwell 3D platform
- 2) Comparison of transient performance of a rotational actuator using Maxwell 2D and Maxwell 3D platforms
- 3) Study the effect of boundary settings on rotating electromagnetic systems using a rotational actuator on Maxwell 2D platform
- 4) Calculation of inductance of a magnetic circuit in presence and in absence of an air gap using Maxwell 2D platform
- 5) Simulation of a single-phase transformer on Maxwell 2D platform and study the effect of finite element mesh on transformer performance
- 6) Study the effect of boundary settings on static electromagnetic systems using a single-phase transformer on Maxwell 2D platform
- 7) Open circuit and short circuit tests on a single-phase transformer using Maxwell 2D and Maxwell 3D platforms and comparison of the equivalent circuit parameters thus estimated
- 8) Calculation of hysteresis and eddy current losses in a three-phase transformer using Maxwell 3D platform
- 9) Design of a three-phase squirrel cage induction machine using RMXprt and study the variation of torque speed characteristics with variation in different design criteria

- 10) Comparison of torque speed characteristics of a three-phase squirrel cage induction machine under constant voltage excitation and constant current excitation using Maxwell 2D platform
- 11) Comparison of torque speed characteristics of a three-phase squirrel cage induction machine generated using field analysis and using equivalent circuit analysis
- 12) Design of a line fed three phase squirrel cage induction machine using ANSYS Motor CAD
- 13) Design of a voltage source inverter fed three phase squirrel cage induction machine using ANSYS Motor CAD

References:

1. ANSYS Maxwell Help; www.ansys.com
2. Getting Started with Maxwell: Designing a Rotational Actuator; www.ansys.com
3. Getting Started with Maxwell: Transient Problem; www.ansys.com
4. Induction Motor for Industrial Application - Design and Analysis with ANSYS Motor-CAD
5. Induction Motor for Power Traction Application - Design and Analysis with ANSYS Motor-CAD

EE6403E ARTIFICIAL INTELLIGENCE AND INDUSTRIAL APPLICATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: **39**

Course Outcomes:

CO1: Apply the fundamentals of Artificial Intelligence.

CO2: Develop problem-solving skills using AI algorithms.

CO3: Develop proficiency in Machine Learning techniques.

CO4: Apply Natural Language Processing (NLP) and Computer Vision.

CO5: Analyze the application of AI for Industrial Applications.

Introduction to Artificial Intelligence

Introduction to Artificial Intelligence: Definition and scope of AI - History and evolution of AI - AI applications in various fields; Problem Solving and Search Algorithms: Problem representation - Uninformed search algorithms (breadth-first search, depth-first search) - Informed search algorithms (heuristic search, A*, etc.); Knowledge Representation and Reasoning: Logic-based knowledge representation - Predicate logic and first-order logic - Inference and reasoning techniques.

Machine Learning Techniques

Machine Learning Basics: Supervised learning, unsupervised learning, and reinforcement learning - Training and testing data - Evaluation metrics; Regression and Classification: Linear regression - Logistic regression - Decision trees and random forests - Support vector machines; Clustering and Dimensionality Reduction: K-means clustering - Hierarchical clustering - Principal Component Analysis (PCA); Neural Networks and Deep Learning: Basics of neural networks - Feedforward neural networks - Convolutional Neural Networks (CNN) - Recurrent Neural Networks (RNN).

Natural Language Processing and Computer Vision

Introduction to Natural Language Processing (NLP): Language processing and understanding - Text preprocessing and feature extraction - Word embeddings; NLP Techniques: Sentiment analysis - Named Entity Recognition (NER) - Text classification; Introduction to Computer Vision: Image representation and preprocessing - Feature extraction and image descriptors - Object detection and recognition; Deep Learning for Computer Vision - Convolutional Neural Networks (CNN) for image classification - Object detection algorithms (e.g., YOLO, Faster R-CNN) - Image segmentation - Simulation practices.

Industrial Applications of AI

AI in Robotics and Automation: Robot control and path planning - Reinforcement learning in robotics - Industrial automation and optimization - AI in Manufacturing and Supply Chain - Predictive maintenance - Quality control and defect detection - Supply chain optimization - Medical image analysis - Disease diagnosis and prognosis - Simulation practices.

References:

1. Stuart Russell and Peter Norvig, "Artificial Intelligence: A Modern Approach", 3rd ed., Pearson, 2021.
2. David L. Poole and Alan K. Mackworth, "Artificial Intelligence: Foundations of Computational Agents", Cambridge University Press, 2017.
3. Tom M. Mitchell, "Machine Learning", McGraw Hill, 1997.
4. Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.
5. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, "Deep Learning", MIT Press, 2016.
6. Daniel Jurafsky and James H. Martin, "Speech and Language Processing", 3rd ed., Pearson, 2019.
7. Steven Bird, Ewan Klein, and Edward Loper, "Natural Language Processing with Python", O'Reilly Media, 2009.
8. Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer, 2010.

EE6427E SUSTAINABLE ENERGY SYSTEMS AND DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: **39**

Course Outcomes:

CO1: Apply sustainable energy systems and their significance in addressing global energy challenges.

CO2: Design various renewable energy sources and their technologies.

CO3: Analyse energy efficiency and conservation practices in sustainable energy systems.

CO4: Design energy storage systems and their integration into the grid.

CO5: Describe the policy, economic, and regulatory aspects of sustainable energy.

Introduction to Sustainable Energy Systems

Introduction to Sustainable Energy - Global energy scenario and the need for renewable energy - Environmental, social, and economic aspects of sustainability - Renewable Energy Sources - Overview of different renewable energy sources (solar, wind, hydro, biomass, geothermal) - Technology, availability, and potential of each renewable energy source; Energy Efficiency and Conservation: Importance of energy efficiency and conservation in sustainable energy systems - Energy-efficient technologies and practices in buildings, industries, and transportation, Energy auditing and energy management techniques - Energy Policy and Planning - Energy policy frameworks and regulations promoting sustainable energy – Over view on Net zero emissions, Circular Economy, Carbon Footprint, Carbon Credits, etc.

Sustainable Energy Technologies

Solar Photovoltaic systems: principles, components, and design considerations; Solar thermal systems: applications, design, and performance analysis; Concentrated solar power (CSP) systems: technologies and operation; Wind turbine technology: types, components, and operation - Wind resource assessment and site selection - Grid integration and power quality issues in wind energy systems; Hydropower systems: types, components, and operation; Tidal, wave, and ocean thermal energy conversion (OTEC) systems; Environmental impacts and considerations in hydropower and ocean energy; Biomass resources: types, availability, and characteristics; Bioenergy conversion technologies: biofuels, biogas, and bioelectricity.

Energy Storage and Grid Integration

Battery technologies: types, characteristics, and applications - Thermal energy storage (TES) systems - Pumped hydro storage (PHS) and other grid-scale energy storage options - Power electronic converters for renewable energy systems - Grid codes and standards for renewable energy integration - Control and management strategies for grid-connected renewable energy systems - Microgrid concepts and components - Intelligent control and energy management in microgrids - Smart grid technologies and their role in sustainable energy systems - Design principles and methodologies for sustainable energy systems - Techno-economic analysis and optimization techniques - Case studies and real-world applications of energy system design.

Sustainable Energy Policy and Economics

Economics of renewable energy technologies - Financial models and incentives for sustainable energy projects - Life-cycle cost analysis and return on investment (ROI) calculations - National and international energy policies for sustainable energy - Feed-in tariffs, net metering, and other policy mechanisms - Carbon pricing and emission trading schemes - Challenges and barriers in transitioning to sustainable energy systems - Energy markets and future trends in renewable energy - Innovations and emerging technologies in sustainable energy.

References:

1. Henrik Lund, "Renewable Energy Systems: A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions," Academic Press, 2014.
2. Jefferson W. Tester, Elisabeth M. Drake, Michael J. Driscoll, Michael W. Golay, and William A. Peters, "Sustainable Energy: Choosing Among Options," The MIT Press, 2005.
3. Gilbert M. Masters, "Renewable and Efficient Electric Power Systems," Wiley, 2004.
4. Vaughn C. Nelson, "Introduction to Renewable Energy," CRC Press, 2011.
5. James F. Manwell, Jon G. McGowan, and Anthony L. Rogers, "Wind Energy Explained: Theory, Design and Application," Wiley, 2010.
6. John A. Duffie and William A. Beckman, "Solar Engineering of Thermal Processes," Wiley, 2013.
7. Robert Huggins, "Energy Storage," Springer, 2018.
8. Jan Pettersen, "Energy Policy Analysis: A Conceptual Framework," Wiley, 2017

EE6428E DISTRIBUTION SYSTEMS MANAGEMENT AND AUTOMATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the architecture, functions and implementation strategies of Distribution Automation Systems and Distribution Management Systems.

CO2: Apply different Intelligent Electronic Devices and Data Concentrators used for Distribution Automation Systems.

CO3: Analyze the usage of different communication systems, its protocols and architectures for implementation for control and automation of Distribution systems.

CO4: Apply automation to substation.

Distribution Automation and Management systems

Distribution Automation (DA) System: Introduction to Subsystems in a distribution control center, Necessity, System Control Hierarchy- Basic Architecture and implementation Strategies for DA- DMS framework: Integration with subsystems, Basic Distribution Management System (DMS) Functions-Real-time DMS applications. Advanced analytical DMS applications, DMS coordination, Customer automation functions.

Intelligent Electronic Devices and Data Concentrators

Intelligent Electronic Devices (IEDs), Evolution of IEDs, IED functional block diagram, The hardware and software architecture of IED, IED Communication subsystem, IED advanced functionalities, Typical IEDs, Data Concentrators and Merging Units.

Wireless and Wired Communication

Communication Systems for Control and Automation- Wireless and wired Communications- DA Communication Protocols, Architectures and user interface OSI seven-layer model Enhanced performance architecture (EPA) model- TCP/IP model-Modbus- IEC 60870-5-101/103/104 .Distributed network protocol 3 (DNP3), Inter-control center protocol (ICCP), Ethernet, IEC 61850, Protocols in the power system: Deployed and evolving.

Substation automation

Justification for Substation automation - Conventional substations. smart devices for substation automation-integrated digital substation-: Technical issues in Substation automation -Substation automation architectures-Comparison of New and existing substations-Substation automation application functions- SA practical implementation: Substation automation laboratory-Hardware design Software components. Case studies in substation automation.

References:

1. James Northcote – Green, Robert Wilson, “Control and Automation of Electrical Power Distribution Systems”, CRC Press, New York, 2007.
2. Mini S. Thomas and John D. McDonald, “Power Systems SCADA and Smart Grid” Taylor & Francis Group, LLC. 2015
3. Stauss C., “Practical Electrical Network Automation and Communication Systems”, Elsevier Eastern Limited. 2003
4. McDonald J. D., “Electric Power Substations Engineering”, CRC Press. Taylor and Francis 2003.
5. Brand K., Lohmann V. and Wimmer W., “Substation Automation Handbook”, Utility Automation Consulting Lohman. 2003.
6. Dr M K Khedkar and Dr G M Dhole, “A Textbook of Electric Power Distribution Automation”, University Science Press, 2011
7. D. Bassett, K. Clinard, J. Grainger, S. Purucker, and D. Ward, “Tutorial Course: Distribution Automation”, IEEE Tutorial Publication 88EH0280-8-PWR, 1988.
8. James A. Momoh, “Electric Power Distribution, Automation, Protection, and Control”, CRC Press, Taylor and Francis Group, 2007

EE6429E SCADA SYSTEMS AND APPLICATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: **39**

Course Outcomes:

CO1: Analyze Supervisory Control Systems (SCADA) as well as architecture and system components.

CO2: Design various industrial communication technologies in SCADA.

CO3: Apply the important components such as PLC, SCADA, DCS, I/O modules and field devices of an industrial automation system.

CO4: Analyse PLC programs in different languages for industrial applications.

Introduction to SCADA & Components

Evolution of SCADA, Hardware, Software, Communication technologies, Monitoring and supervisory functions, SCADA Functional requirements and Components, SCADA Hierarchical concept, SCADA architecture, General features, SCADA applications in Utility Automation, Industries, Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), Communication Network, Master-slave, SCADA Server, SCADA/Human Machine Interface (HMI) Systems, Various SCADA architectures, single unified standard architecture.

SCADA Communication

SCADA Communication: various industrial communication technologies -wired and wireless methods and fiber optics, IEC 61850-based communication, Open standard communication protocols.

Remote Terminal Unit (RTU)- configuration, communication interface, control processor, Analog input/ output modules, Digital input/output module, Discrete control, Analog control, Pulse control, Serial control, Power supply module, Testing, and maintenance

Master Terminal units (MTU) – communication architecture, Features, and functions, Master station software, local area networks, Application, and data storage.

SCADA Applications

SCADA Applications: SCADA operating costs, Utility applications- Transmission and Distribution sector - operations, monitoring, analysis and improvement, scanning and communications, Operator Interface- alarming, system security, control change screens, status screens, graphics and trends, and reports.

Automatic control Industries - oil, gas, and water. Case studies, Implementation, Simulation Exercises.

Programmable Logic Controllers

Evaluation of PLC, PLC Architecture, Basic Structure. PLC Programming: Ladder Diagram – Basic instructions, Ladder diagram symbols, Timer and Counter instruction- Arithmetic and logical instruction – MCR, PID controller, and other essential instruction sets - Case studies and examples for each instruction set. PLC Communications and Networking, PLC Selection: I/O quantity and Type, Memory size and type, Programmer Units, Programming of PLC using simulation software – Real-time interface and control of process rig/switches using PLC, Interfacing PLC to SCADA.

References:

1. Stuart A. Boyer, “SCADA-Supervisory Control and Data Acquisition”, Instrument Society of America Publications, USA,2004.
2. Gordon Clarke, Deon Reynders, “Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems”, Newnes Publications, Oxford, UK,2004.
3. William T. Shaw, “Cybersecurity for SCADA systems”, PennWell Books, 2006.
4. F.D. Petruzella, “Programmable Logic Controllers”, Tata Mc-Graw Hill, 3rd ed., 2010
5. David Bailey, Edwin Wright, “Practical SCADA for industry”, Newnes, 2003
6. Edward J.M. Colbert and Alexander Kott, “Cyber-security of SCADA and other industrial control Systems”, Springer, 2016.
7. Dieter K. Hammer, Lonnie R. Welch, Dieter K. Hammer, “Engineering of Distributed Control Systems”, Nova Science Publishers, USA, 1st ed., 2001

EC6105E ELECTRONIC PRODUCT DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	2	7	4

Total Sessions: **26L+26P**

Course Outcomes:

CO1: Assess the requirement for a new product by conducting a market survey.

CO2: Infer working knowledge of several electronic components and integration of these components to form a final product.

CO3: Examine the various stages involved in an electronic product development.

CO4: Build prototype of an electronic product undergoing different stages of product development life cycle.

Lecture Sessions:

Life cycle of electronic products, product planning - Customer need identification, feasibility study, specifications etc.

Design and development process, technical drawings, circuit diagrams, computer aided design. Reliability of electronic products: Calculation principles – Terminologies, parameters, mathematical modelling, failure of electronic components and systems, reliability analysis design for manufacturing, design for testing, design for environment.

Industrial design, aesthetics, ergonomics, thermal design – Power dissipation in electronic components, temperatures of components and systems, electrical and thermal network methods of calculations, heat transfer, methods to increase heat transfer.

Practical Sessions

The students need to implement the prototype model of an electronic product undergoing different stages of product development life cycle, which include: • Requirements/market study/feasibility study • Finalizing the Specifications • Mechanical design • Ergonomics and Aesthetics • Hardware Design o Component selection o Schematic Entry o Layout Design o PCB manufacturing and assembly • Mechanical Assembly • Software Design • Testing.

In this process students will be familiarized with different tools and machines like Shop bot, 3D printer, Laser cutter, PCB fabrication machine & soldering tools.

References:

1. Jens Lienig, Hans Bruemmer, Fundamentals of Electronic Systems Design, Springer, 2017.
2. Karl T. Ulrich, Steven D. Eppinger, Product Design and Development, Mc Graw Hill, 2016.
3. V.B. Baru R.G.Kaduskar, Electronic Product Design, Wiley India 2011.
4. Tony Ward and James Angus, Electronic Product Design, Chapman & Hall 1996

ZZ6001E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: **26**

Course Outcomes:

CO1: Explain the basic concepts and types of research

CO2: Develop research design and techniques of data analysis CO3: Develop critical thinking skills and enhanced writing skills

CO4: Apply qualitative and quantitative methods for data analysis and presentation

CO5: Implement healthy research practice, research ethics, and responsible scientific conduct

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation,

Research Plan and Path

Developing a Research Plan: Reviewing the literature- Referencing – Information sources – Information retrieval – Role of libraries in information retrieval – Tools for identifying literatures – Reading and understanding a research article – Critical thinking and logical reasoning; Framing the research hypotheses, Converting research Question into a Model; Data collection- Types of data-Dataset creation- Primary and Secondary data- Scales of measurement- Sources and collection of data- Processing and analysis of data-Understanding Data-statistical analysis, displaying of data-Data visualization-Data interpretation; Research design- Qualitative and Quantitative Research- Designing of experiments- Validation of experiments- Inferential statistics and result interpretation

Scientific Conduct and Ethical Practice

Plagiarism– Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work-Conduct in the workplace and interaction with peers – Intellectual property: IPR and patent registration, copyrights; Current trends – Usage and ethics of AI tools in scientific research.

References:

1. Leedy, P D, *Practical Research: Planning and Design*, USA: Pearson, Twelfth ed., 2018.
2. Krishnaswamy, K. N., Sivakumar, A. I., and Mathirajan, M., *Management Research Methodology*, Pearson Education, 2006.
3. Tony Greenfield and Sue Greener., *Research Methods for Postgraduates*, USA: John Wiley & Sons Ltd., Third ed., 2016.
4. John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, USA: Sage Publications, Sixth ed., 2022.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: **26**

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.

CO2: Collaborate on various writing projects for academic and technical purposes.

CO3: Combine attributes of critical thinking for improving technical documentation.

CO4: Adapt technical writing styles to different platforms.

Technical Communication

Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics

Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements – Proof reading

Technical Documentation

Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D., *Longman advanced learner's grammar, a self-study reference & practice book with answers*. Pearson Education Limited, 2018.
2. Gerson, S. J., & Gerson, S. M., *Technical writing: Process and product*, Pearson, 2009.
3. Kirkwood, H. M. A., & M., M. C. M. I., *Hallidays introduction to functional grammar* (4th ed.), Hodder Education, 2013.
4. Markel, M., *Technical Communication* (10th ed.). Palgrave Macmillan, 2012.
5. Tuhovsky, I., *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills*, Rupa Publications India, 2019.
6. Williams, R., *The Non-designer's Design Book*. Peachpit Press, 2014.

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.

CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.

CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.

CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V., *Patterns of entrepreneurship management*. John Wiley & Sons, 2022.
2. Kuratko, D. F., *Entrepreneurship: Theory, Process, and Practice*. Cengage learning.
3. Barringer, B. R., *Entrepreneurship: Successfully launching new ventures*, Pearson Education India, 2015.
4. Rajiv Shah, Zhijie Gao, Harini Mittal, *Innovation, Entrepreneurship, and the Economy in the US, China, and India*, Academic Press, 2014.
5. Sundar, K., *Entrepreneurship Development*, 2nd Ed., Vijaya Nickol Imprints, Chennai, 2022.
6. E. Gordon, Dr. K. Natarajan., *Entrepreneurship Development*, 6th Ed, Himalya Publishers, Delhi, 2017.
7. Debasish Biswas, Chanchal Dey, *Entrepreneurship Development in India*, Taylor & Francis, 2021.