TRIPURA UNIVERSITY
(A CENTRAL UNIVERITY)

CURRICULUM STRUCTURE

OF

4 YEARS

BACHELOR OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING (EE)

6th Semester

2021

6th SEMESTER

Sl. No.	Course Category	Subject Code	Subject Title	L	T	P	Contact Hours/week	Credit	Total Marks
1.	Program Core-21	PC EE 601	Power System-II	3	0	0	3	3	100
2.	Program Core-22	PC EE 602	Electric Drives	3	0	0	3	3	100
3.	Program Core-23	PC EE 603	Power System Protection & Switchgear.	3	0	0	3	3	100
4.	Program Core-24	PC EE 604	Signal and Systems	3	0	0	3	3	100
5.	Program Core-25	PC EE 605	Electrical Engineering Simulation laboratory	0	0	2	2	1	100
6.	Program Core-26	PC EE 606	Control Systems Laboratory	0	0	2	2	1	100
7.	Program Core-27	PC EE 607	Power System Laboratory	0	0	2	2	1	100
8.	Program Elective-1	1.PE EE 608/1	Digital Signal Processing	3	0	0	3	3	100
		2. PE EE 608/2	Wind and Solar Energy						
		3. PE EE 608/3	High Voltage Engineering						
9.	Project - 1	PR EE 609	Mini Project	0	0	6	6	3	100
			Total :	15	0	12	27	**21**	**900**

POWER SYSTEM – II

Course Code	PCEE 601
Course Title	Power System II
Number of Credits	03 (3L:0T:0P)
Prerequisites	Power System-I, basic circuit laws, Engineering Mathematics &Physics.
Course Category	Program Core (PC)
Number of classes	38

Course Outcomes:

After Completing this course, students will be able to		Knowledge Level
CO -1	Use numerical methods to analyse a power system in steady state	K3
CO -2	Understand stability constraints in a synchronous grid.	K2
CO-3	Understand methods to control the voltage, frequency and basics of power system economics	K2
CO -4	Understand the monitoring and control of a power system	K2

Course Content:

Module 1: Power Flow Analysis (8 hrs.)

Review of the structure of a Power System and its components. Analysis of Power Flows: Formation of Bus Admittance Matrix. Real and reactive power balance equations at a node. Load and Generator Specifications. Application of numerical methods for solution of nonlinear algebraic equations – Gauss Seidel and Newton-Raphson methods for the solution of the power flow equations. Computational Issues in Large-scale Power Systems.

Module 2: Stability Constraints in synchronous grids (10 hrs.)

Swing Equations of a synchronous machine connected to an infinite bus. Power angle curve. Description of the phenomena of loss of synchronism in a single-machine infinite bus system following a disturbance. Transient stability studies by equal area criterion. Power Control: Concept of Load frequency control in multi- area system and static response of two area system.

Module 3: Short Circuit Studies, Travelling waves and Basic Pricing (10 hrs.)

Short circuit studies: Formation of bus impedance matrix, systematic three phase fault computation using bus impedance matrix. Unbalanced fault analysis using bus impedance matrix. Travelling wave concept- step Response- Bewely's lattice diagram- Standing waves and natural frequencies- reflection and refraction of travelling waves. Surge Impedance Loading. Basic Pricing Principles: Incremental fuel rate curves, incremental fuel cost curve, constraints in economic operation power system. Cost function for economic operation of a two-area power system.

Module 4: Control and Monitoring (10 hrs.)

Automatic Generation Control. Generation and absorption of reactive power by various components of a Power System. Excitation System Control in synchronous generators, Automatic Voltage Regulators. Shunt Compensators, Static VAR compensators and STATCOMs. Tap Changing Transformers. Overview of Energy Control Centre Functions: SCADA systems. Phasor Measurement Units and Wide-Area Measurement Systems.

References/Suggested Learning Resources:

1. A.Chakraborthy and S. Halder, "Power System Analysis, Operation and Control", PHI.
2. T.K Nagsarkar & M.S. Sukhija, "Power System Analysis" Oxford University Press, 2007.
3. Hadi Sadat; "Power System Analysis", Tata McGraw Hill.
4. Kabir Chakraborty & Abhiji Chakraborty, "Soft Computing Techniques in Voltage Security Analysis", Springer.
5. Kothari & Nagrath, "Modern Power System Analysis" Tata McGraw Hill.
6. Electrical power systems, Ashfaq Husain, CBS Publication.

ELECTRIC DRIVES

Course Code	PCEE602
Course Title	Electrical Drives
Number of Credits	3 (L: 3, T: 0, P: 0)
Prerequisites	Electrical Machine and Power Electronics
Course Category	Program Core-22(PC-22)
Number of classes	36 hours

Course Outcome:-

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

CO No.	CO Description	K-level
PCEE602.1	Explain basic terminology, Four quadrant representation and various braking in drives system.	K2
PCEE602.2	Extend knowledge about Electric traction System.	K2
PCEE602.3	Apply the concept of solid state control of DC and AC drives.	K3

PCEE602.4	Analyze the total converter system for AC and DC drives using various converters and starting of dc and ac motors.	K4

Course Content:-

Module 1: Introduction (10 hours):
Drive specifications, Basic terminology: base speed, speed ratio, constant torque drive, constant hp drive, etc. Four quadrant representation, dynamics of loading of motor with different types of mechanical load. Heating and cooling of motors, operating duty cycles. Choice of couplings and bearings. Acceleration time, energy loss in starting. Effect of flywheels. Regeneration in drives: Dynamic braking, regenerative braking, dc injection, plugging.

Module 2: Electric Traction System and DC drives (10 hours):
Electric Traction: General introduction and requirements, speed-time curve mechanics in train movement. DC and AC traction supplies. Current collectors. Traction motors. Linear motors and magnetic levitation. Solid state control of dc motors – basic principles. Armature current control with constant flux and field weakening. Simple modeling of a separately excited dc motor. Drive schemes with armature voltage feedback, IR compensation, and tacho feedback for both constant flux and field weakening.

Module 3: Induction Motor Drives (8 hours):
Solid state control of induction motors – basic principles of Induction motor based Drives, Detail description, specifications & implementation of Induction Motor based Static-Kramar Electric Drive System. V/f control with constant flux and field weakening using SCR & IGBT. Simple modelling of an induction motor. Drive schemes with terminal voltage feedback and slip-compensation, Implementation using speed feedback for both constant flux and field weakening.

Module 4: Realisation of the total converter system and starting methods (8 hours):
Realisation of the total converter system for ac and dc drives using choppers, Phase controlled rectifiers, Dual converters, Voltage Source Inverters (VSI), Current Source Inverters (CSI). Current Controlled VSI and Cycloconverters. Basic operating principles and characteristics of the schemes. Protection schemes for overall drive systems. Power electronic controlled starting of dc and ac motors.

References/ Suggested Learning Resources:-
1. Fundamentals of Electrical Drives: G.K. Dubey.
2. Power Electronics and Motor Control : W. Shepherd, L.N. Hulley & D.T.W. Liang
3. Electric Drives : N.K. De, P.K. Sen.
4. Power Semiconductor Controlled Drives: G.K. Dubey

5. Control of Electric machines: Irving L. Kosow
6. Modern Electric Traction: H. Partab.
7. A First Course on Electrical drives: S.K. Pillai
8. Electric Motor Drives: R. Krishnan
9. Electric Drives: M. Chilikin.

POWER SYSTEM PROTECTION & SWITCHGEAR

Course Code	PC EE-603
Course Title	Power System Protection & Switchgear
Number of Credits	3 (L: 3, T: 0, P: 0)
Prerequisites	Power System
Course Category	Program Core (PC)
Number of classes	38 hours

Course Outcome: After the completion of the course Students will be able to

CO No	CO Description	K-level
CO-1	Identify the main components and features of protection scheme and explain the phenomena of circuit breaking	K3
CO-2	Explain the various types of existing circuit breakers, their design and constructional details and its use in power system protection.	K5
CO-3	Understand the various conventional relays, their design and latest developments and apply them in protective scheme.	K2
CO-4	Analyze and design the protection system for application in power system.	K4

Course Content:-

MODULE-1: Components of Protection system and Circuit Breaking (10 hrs.)
Substations Equipment's, arrangement of Circuit Breakers, Isolators, Bus bars, instrument transformers, current limiting Reactors in Power System. Types of earthing, Earthing Mat. General requirements of circuit breakers. Auto- reclosing feature. Formation of electric arc. Arc build-up and quenching theory, recovery voltage and RRRV, Arc restriking phenomena.

MODULE-2: Circuit Breakers and Protective Relaying (9 hrs.)
Problems of capacitive and low inductive current interruptions. Rating of circuit breakers and effect of transient current on it. Different types of arc quenching media and special devices for arc quenching. Different types of circuit breakers - their relative merits and demerits. Specific field of usages. Testing of circuit breakers. D.C circuit breaking. Fundamental principles of protective relays, their properties and block diagrams. Zones of protection, Primary and Back-

up protection.

MODULE-3: Different schemes of Protection (10 hrs.)
Single input relays, over current, earth fault relays. Reverse Power relay. Principle and application of directional over current and earth fault relays. Principle of 2-input comparison, two and multi-input comparators. Distance relays their settings, errors and remedies to errors. Differential relays current and voltage comparison. Time graded Feeder Protection: radial, ring mains protection.

MODULE-4: Equipment Protection and Protection against over-voltages (9 hrs.)
Transformer Protection-techniques & related Specifications. Motor & Generator protection Systems, Different types of pilot protection wire, carrier and wireless pilot. Carrier aided distance protection. Carrier phase comparison schemes. Protection against Over voltage due to lightning. Surge diverters, rod gap, horn gap, lighting arresters, surge absorber for surge protection.

References / Suggested Learning Resources:-

1. Switchgear & Protection, by J.B.Gupta.- S.K. Kataria & Sons
2. Power System Protection & Switchgear, by Badri Ram, D.N.Vishwakarma.- McGraw Hill.
3. Electrical Power System by C.L. Wadhwa,- New Age International
4. Protective Relays – Their theory And Practice Vol-I & II, by A.R.Van. C. Warrington, john Willey
5. Power System Protection, by S.P.Patra, S.K.Basu & S.Choudhuri,- Oxford & IBH
6. Power System Protection & Switchgear, by B.Ravindranath & M.Chander, Willey Eastern
7. Switchgear & Protection, by S. S. Rao, Khanna Publishers.

8. Power System Protection, Vols.I, II & III, by Electricity Council, Macdonald & Co.
9. The J & P Switchgear Book, Johnson & Philips Ltd. Newness Butterworths.
10. Power System Protection, Vols.I, II, III & IV, by The Electricity Training Association

SIGNALS AND SYSTEMS

Course Code	PC EE 604
Course Title	Signals and Systems
Number of Credits	3(L:3, T:0, P:0)
Prerequisites	10+2 Mathematics, Circuits Theory
Course category	Program Core-24
Number of Classes	38

Course Outcome: Students would be able to

CO number	CO Description	k-level
CO-1	Understand the Characteristics of different signals and functions.	K2
CO-2	Apply their knowledge on the characteristics of Fourier series and Transforms, spectral density and white noise	K3
CO-3	Design different active filters based on the concept of Frequency responses of LTI systems.	K6
CO-4	Develop the model of different Electrical, Mechanical, Electro-mechanical systems which are very much essential for analysis of any system using Fourier transform, Z-transform etc.	K6

MODULE-1: Basic Operations on Signals (10 hrs.):

Classification of signals: deterministic & random signals, continuous-time(CT) & discrete time (DT) signals, Power & Energy signals, causal & non-causal signals. Time-domain operations on CT signals. Mathematical descriptions of deterministic CT signals, Singularity functions. Impulse (Dirac Delta) function and its properties. Decomposition of simple aperiodic waveforms in terms of singularity-function components. Convolution Integral: analytical & graphical convolution, properties of convolution.

MODULE-2: Fourier Transform (10 hrs.):

Review of Trigonometric Fourier Series for CT periodic signals. Exponential Fourier Series and Line- Spectra. Gibbs phenomenon. Properties of Fourier Series. CT Fourier Transform & Integral. Generalized Fourier Transform. Parseval"s theorem. Properties of Fourier Transform. Power Spectral Density of periodic signals. Energy Spectral Density. Concept of autocorrelation functions for deterministic signals. White Noise and its necessity.

MODULE-3: Filter Design (8 hrs.):

Frequency response of LTI systems: Definitions, significance, frequency responses of first-order & second-order systems. Standard description of Transfer function of 1st & 2nd order Active Filters and their frequency responses, Design of 2nd Order Active Filters. Design of Butterworth and Chebyshev active filters.

MODULE-4: Concept of Systems and Z-transform (10 hrs.):

General concept of Systems: Classification, Modeling of Dynamic Systems: Mechanical systems including rotary systems, gears, Electro-mechanical systems, DC motors, moving coil speakers, ballistic galvanometers, Thermal systems: first order and second order models, Electrical circuit analogues. Z-transformation, Inverse Z-transformation and theorems of Z-transformation.

References / Suggested Learning Resources:-

1. Simon Haykin and Barry Van Veen, —Signals and Systems.
2. B.P. Lathi, —Principles of Linear Systems and Signals. (International Version).
3. Tarun Kumar Rawat, —Signals and Systems.
4. P. Ramesh Babu, —Signals and Systems.
5. F.F. Kuo, —Network Analysis and Synthesis.
6. B.C. Kuo, —Automatic Control Systems.
7. I. J. Nagrath and M. Gopal, —Control System Engineering.
8. D.K. Lindner, —Introduction to Signals and Systems.
9. S. Dasgupta, —Control System Theory.

ELECTRICAL ENGINEERING SIMULATION LAB

Course Code	PC EE 605
Course Title	Electrical Engineering Simulation Lab
Number of Credits	1 (L: 1; T: 0; P: 0)
Prerequisites	Advanced Computer Techniques in Power Systems; Control system; Network theory; Basic Electronics
Course Category	Program Core-25
Number of Classes	24

Course Outcome: Students will be able to

CO Number	CO Description	K-level
CO-1	Model different types of electrical power Transmission lines.	K3
CO-2	Develop Bus Admittance matrices for multi-bus power network.	K3
CO-3	Analyze time domain and frequency domain characteristics of different types of control systems	K4
CO-4	Design half wave and full wave uncontrolled rectifier circuit using MATLAB	K6

Course Content:
List of experiments:

1. Determination of transfer function and its pole and zeros of 1^{st}, 2^{nd}& 3^{rd} order systems
2. Time response analysis of series RLC series circuit.
3. Time response analysis of a second order system by using Simulink.
4. Frequency domain stability analysis of 3^{rd} order system.
5. Determination of ABCD parameter of short, medium and long transmission line.
6. Determination of voltage regulation and efficiency of transmission line.
7. Design a single phase half wave rectifier circuit and show voltage and current waveforms of load.

8. Design a single phase full wave rectifier circuit and show voltage and current waveforms of load.
9. Load flow analysis of power system network using ETAP.
10. Closed-loop speed control of D.C. motor: Stability analysis by root-locus method.
11. Formation of bus admittance matrix matrices for multi-bus power network.

References / Suggested Learning Resources:

1. Beginning MATLAB and Simulink: From Novice to Professional; Edition by Sulaymon Eshkabilov. Apress; 1st ed. edition (November 29, 2019)
2. MATLAB For Beginners: A Gentle Approach; by Peter I. Kattan; Create Space Independent Publishing Platform (April 11, 2008).
3. Chakraborthy, Soni,Gupta & Bhatnagar, "Power System Engineering", Dhanpat Rai & Co.
4. Wadhwa, C.L., "Electric Power Systems", Second Edition, Wiley Eastern Limited, 1985.
5. V.K. Mehta, "Principles of Electronics",S Chand, 2004.

CONTROL SYSTEMS LABORATORY

Course Code	PCEE-606
Course Title	Control Systems Laboratory
Number of Credits	1(L : 0, T :0, P:2)
Prerequisites	Electromagnetic Field Theory
Course category	Program Core-26
Number of Classes	24

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

CO Number	Course description	K-level
PCEE-606:OC.01	Determine the Transfer function of DC servomotor from Experimental results.	K3
PCEE-606:OC.02	Examine the characteristics of time response of Position control system from Hardware experiments and their Steady-state analysis.	K4
PCEE-606:OC.03	Understand the effect of Velocity feedback in position control systems.	K2
PCEE-606:OC.04	Evaluate the effect of Pole Placement by state feedback for the better control of Electro-Mechanical Systems.	K5

List of Experiments:

The following Experiments are required to be carried out using Hardware based Control

System Trainers, it is desirable that all Hardware based Control System Trainers are required to be interfaced with the computer for better understanding of Experiments for analysis. .

1. Determination of Transfer function of D.C. Servo Motor by applying Step input and verification of Transfer function from frequency response graph of D,C. Servomotor (at different Mechanical loadings)..
2. Determination of steady state error of DC Servomechanism due to Step, Ramp and Parabolic inputs.

3. Position Control of second order DC Servomechanism and determination of Parameters of the System fromthe experimental Results.

4. Study the effect of Velocity feedback on Position control of DC Servomechanism and determination of Parameters due to velocity feedback at different values.

5. Experiments for speed Control of D.C. Servo Motor with PI Controller + derivative output Compensation technique.

6. Position control of D.C. Servo Mechanism using P, P+I, P+D, P+I+D Controllers to study the characteristics of second order System and indication of Position Control using Gray-coded disk.

7. Position Control of Electro-Mechanical Plant having at least two mechanically coupled discs with feedback for the identification of controlled positions of discs using Pole placement of the Plant by State feedback of the System.

8. Study of disturbances of Torques on PD & PID Rigid body system using Electro-Mechanical Plant having at least two Mechanically Coupled discs with feedback arrangements.

References / Suggested Learning Resources:

1. Norman S. Nise, Control Systems Engineering, 6th edition, Wiley, 2011.
2. I.J.Nagrath and M.Gopal, Control Systems Engineering, 5th edition, New Age International, 2009.
3. D. Roy Chowdhury, Modern Control Engineering, PHI Pulication.
4. Benjamin C. Kuo and Farid Golnaraghi, Automatic Control Systems, 9th edition, Wiley; 2009.
5. M. Gopal, Control Systems Principles and Design, 3rd edition, Tata Mgraw Hill, 2008.
6. Naresh K. Sinha, Control Systems, 3rd edition, New Age International, 2004.
7. Richard C. Dorf and Robert H. Bishop, Moderlinearn Control Systems, 12th Edition
8. B. C. Kuo, Digital Control System.
9. Ogata, Discrete Data Control System.

POWER SYSTEM LABORATORY

Course Code	PC EE 607
Course Title	Power System Laboratory
Number of Credits	1 (L :0, T :0, P:2)
Prerequisites	Power System; Electrical machine
Course category	Program Core-27
Number of Classes	26

Course outcomes:

CO Number	Course description After the completion of the course students will be able to	K-level
CO1	Determine the constants of Transmission lines	K5
CO2	Identify different types of Distribution networks	K3
CO3	Analyse the characteristics of different types of relays.	K4
CO4	Understand different types of protection scheme of power network.	K2

List of Experiments:

1. No load test &Ferranti effect of electrical transmission lines.
2. Determination of transmission line constants (ABCD) by experimental measurement using 2-port method as well as by knowing components values and its verification.
3. Load Test & Calculation of Regulation, efficiency of Transmission Line.
4. Verification of practical results with theoretical calculations for symmetrical faults of transmission lines.
5. Verification of practical results with theoretical calculations for unsymmetrical faults of transmission lines.
6. Study the various type of dc distribution network system like
   - Distribution system fed at one end
   - Distribution system fed at both end
   - Distribution system fed at centre
   - Ring Main distribution system

7. Study the working principle of Bucholtz relay by Experiments.
8. Study of the working principle percentage biased single phase differential relay by Experiments.

9. Study (Practical) the three phase AC Motor protection using numerical type power systems relay consisting

- Testing of motor protection relay with Over-Current Fault
- Testing of motor protection relay with Motor Earth- Fault
- Testing of motor protection relay with Motor Rotor Locked Fault
- Testing of motor protection relay with Motor Un-Balanced Voltage Fault
- Testing of motor protection relay with Under Current Fault
- Testing of motor protection relay with Thermal Fault Protection

10. Study and testing of over voltage relay with different voltage & time setting multiplier.
    - Measurement of relay tripping time.
    - Plotting the IDMT characteristics of over voltage relay.

11. Study and testing of under voltage relay with different voltage setting multiplier.
    - Measurement of relay tripping time
    - Plotting the IDMT Characteristics of Under voltage relay.

DIGITAL SIGNAL PROCESSING

Course Code	PE EE 608/1
Course Title	Digital Signal Processing
Number of Credits	4(L:3, T:0, P:0)
Prerequisites	Signal and System
Course category	Program Elective-1
Number of Classes	38

Course Outcome
After Completion of the course student would be able to

CO Number	CO Description	k-level
CO-1	Understand the concept of signal processing for higher courses of Electrical Engineering and also for Industrial applications and research works.	K2
CO-2	Analyze real world signals in digital format and understand transform-domain (Fourier -transforms) representation of the signals.	K4
CO-3	Analyze the fundamental principles and techniques of digital signal processing for understanding and designing new digital systems and for continued learning.	K4
CO-4	Design digital filters with different window techniques and learn the theory of different kind of modern digital signal processor.	K6

MODULE-1 Basics of Signal and Systems (10 hrs.):

Description of Signals and Systems: Types of signals and their characteristics, Analog Signal Processing versus Digital Signal Processing. Frequency domain representation of uniformly-sampled signals. Anti-alias filter. Power and energy sequences. Odd and even sequences.

Causal, anti-causal and two sided sequences. Periodic sequences. Time-domain operation on sequences--- time scaling, time-reversal, time-shifting.. Discrete-time LTI systems, Discrete-time convolution, its properties and interconnection of LTI systems. Recursive and Non-recursive systems, FIR and IIR systems. Ideal interpolation formula for reconstructing analog signals from their samples. Image rejection post filtering, compensated reconstruction filter.

MODULE-2 Discrete Time Fourier Transform(10 hrs.):

Discrete-time Fourier transform: Definition of Fourier transform (FT), important properties of FT, properties of FT for real-valued sequences, use of FT in signal processing, FT of special sequences, the inverse FT, FT of the product of two discrete-time sequences, program to evaluate the FT by computer. Discrete Fourier Transform: The definition of the Discrete Fourier Transform (DFT), computation of the DFT from the discrete-time sequence, properties of the DFT, circular convolution, performing a linear convolution with the DFT, computations for evaluating the DFT, programming the DFT, increasing the computational speed of the DFT, intuitive explanation for the decimation-in-time FFT algorithm, analytic derivation of the decimation-in-time FFT algorithm, some general observations about the FFT.

MODULE-3 Digital Filter Structure (8 hrs.):

Digital filter: Definition and anatomy of a digital filter, frequency domain description of signals and systems, typical applications of digital filters, filter categories: IIR and FIR, recursive and non-recursive. Digital Filter Structures: The direct form I and II structures, Cascade combination of second-order sections, parallel combination of second-order sections, Linear-phase FIR filter structures, Frequency-sampling structure for the FIR filter. Design of digital filter by Fourier series method. Frequency response of digital filters, realization problems. Direct realization of linear phase FIR digital filters, effect of truncation of impulse response, circular complex convolution integral, Gibbs phenomenon.

MODULE-4 Design of Filter using window function (10 hrs.):

Frequency domain characteristic of common window functions. Design of brick-wall type low pass, high pass, band pass FIR digital filters. Design of linear phase FIR filters by the frequency sampling method. Design of optimum equiripple linear phase FIR filters. FIR digital filters for off-line analysis for one-dimensional (1-D) and two-dimensional (2-D) data. 2-D finite impulse sequence of digital FIR filter. Digital signal processors: Processor architecture: Von Neumann architecture, Harvard architecture, modified Harvard architecture, multiply, accumulate operation, benchmarks.

References / Suggested Learning Resources:

1. Digital Signal Processing: Principles, Algorithms & Applications – J.G. Proakis and M. G. Manolakis.

2. Signals and Systems-- Simon Haykin and Barry Van Veen .
3. Network Analysis and Synthesis--- M.E. Van Valkenburg
4. Principles of Linear Systems and Signals (International Version)- B.P. Lathi.
5. Discrete-Time Signal Processing--- Oppeinham, Schaffer and Buck.
6. Digital Signal Processing-- P. Ramesh Babu.
7. Digital Signal Processing: A Computer Based Approach – S. K. Mitra.
8. Digital Signal Processing – J. R. Johnson.

WIND AND SOLAR ENERGY

Course Code	PEEE-608/2
Course Title	Wind and Solar Energy
Number of Credits	3 (L: 3, T: 0, P: 0)
Prerequisites	Power System
Course Category	Program Elective-1
Number of classes	36 hours

Course Outcome:

CO Number	CO Description	K-level
CO-1	Understand the energy scenario and the consequent growth of the power generation from renewable energy sources	K2
CO-2	Understand the basic physics of wind and solar power generation	K2
CO-3	Apply the power electronic interfaces for wind and solar power generation	K3
CO-4	Analyze the issues related to the grid-integration of solar and wind energy systems	K4

Course Content:

Module 1: Solar Resource and Solar thermal power generation (8 hours):
Introduction, Solar Radiation Spectra, Solar Geometry, Earth Sun Angles, Observer Sun Angles, Solar Day Length, Estimation of Solar Energy Availability. Solar Thermal Power Generation Technologies, Parabolic Trough, Central Receivers, Parabolic Dish, Fresnel, Solar Pond, Elementary Analysis.

Module 2: Wind Power and Wind generator topologies (10 hours):
History of Wind Power, Indian and Global Statistics, Wind Physics, Betz Limit, Tip Speed Ratio, Stall and Pitch Control, Wind Speed Statistics-Probability Distributions, Wind Speed and Power-Cumulative Distribution Functions. Review of Modern Wind Turbine Technologies, Fixed and Variable Speed Wind Turbines, Induction Generators, Doubly-Fed Induction Generators and Their Characteristics, Permanent-Magnet Synchronous Generators, Power

Electronics Converters, Generator-Converter Configurations, Converter Control.

Module 3: Solar photovoltaic (8 hours):
Technologies- Amorphous, Monocrystalline, Polycrystalline; V-I Characteristics of a PV Cell, PV Module, PV Array, Power Electronic Converters for Solar Systems, Maximum Power Point Tracking (MPPT) Algorithms, Converter Control.

Module 4: Network Integration Issues (10 hours):
Overview of Grid Code Technical Requirements, Fault Ride-Through for Wind Farms - Real and Reactive Power Regulation, Voltage and Frequency Operating Limits, Solar PV and Wind Farm Behavior During Grid Disturbances, Power Quality Issues, Power System Interconnection Experiences in the World, Hybrid and Isolated Operations of Solar PV and Wind Systems.

References / Suggested Learning Resources:

1. T. Ackermann, "Wind Power in Power Systems", John Wiley and Sons Ltd., 2005.
2. G. M. Masters, "Renewable and Efficient Electric Power Systems**",** John Wiley and Sons, 2004.
3. S. P. Sukhatme, "Solar Energy: Principles of Thermal Collection and Storage", McGraw Hill, 1984.
4. H. Siegfried and R. Waddington, "Grid integration of wind energy conversion systems", John Wiley and Sons Ltd., 2006.
5. G. N. Tiwari and M. K. Ghosal, "Renewable Energy Applications", Narosa Publications, 2004.
6. J. A. Duffie and W. A. Beckman, "Solar Engineering of Thermal Processes", John Wiley & Sons, 1991.

HIGH VOLTAGE ENGINEERING

Course Code	PEEE-608/3
Course Title	High Voltage Engineering
Number of Credits	3 (L: 3, T: 0, P: 0)
Prerequisites	Power System
Course Category	Program Elective-1
Number of classes	36 hours

Course Outcome:

CO Number	CO Description	K-level
CO-1	Understand the different phenomena of over voltages, switching surges and practices of grounding	K2
CO-2	Understand the different phenomenon of high voltage power transmission and distribution	K2

CO-3	Understand breakdown of gases, liquid and solids	K2
CO-4	Apply different methods of generation of high voltages	K3
CO-5	Analyze the different high voltage measurement techniques	K4

Course Content:

Module 1: High Voltage Power Transmission and Distribution (8 hours):

High voltage power transmission and distribution, Insulators: Type of insulators and their applications, voltage distribution and string efficiency of disc insulators. Corona: Theory of corona formation, corona loss and radio interference. Overvoltage phenomena: Lightning and switching surges, Travelling waves: Reflection and refraction w.r.t. different type of line terminations, Overvoltage protection: Grounding practice and overvoltage due to earth fault, lightning arresters and surge suppressors.

Module 2: High Voltage Cables and Breakdown Mechanism (10 hours):
Insulation coordination scheme of open-air substation, High voltage cables: Single core, belted, XLPE and gas-filled. Inter-sheath grading, Requirement of extra high voltage cables, Bushings: Non-condenser and condenser bushings, field distribution. Breakdown in gases, Townsend mechanism, Paschen's law, Streamer breakdown, Breakdown under Surge Voltages, Different types of breakdown in solid dielectrics, Different types of breakdown in liquids, Partial discharge.

Module 3: Statistical Methods Generation of High Voltages (8 hours):
Statistical Methods Generation of High AC Voltage, Testing transformer and its cascade connection, single-phase series resonance circuit, Generation of High DC Voltage, Single-stage and multi-stage symmetric as well as asymmetric voltage multiplier circuits, Generation of Impulse Voltage Single-stage and multi-stage impulse generators circuits.

Module 4: Measurement of High Voltages (10 hours)
Triggering and synchronization with CRO for Measurement of Peak value of high AC Voltage, Frequency dependent method: Chubb & Fortescue Method, Frequency independent methods: Davis-Bowdler Method, Rabus Method, Sphere-Gap Method Measurement of RMS value of high AC Voltage Capacitive Voltage, Transformer, Potential Dividers, Electrostatic Voltmeter Measurement of High DC Voltage Ammeter in series with high resistance Measurement of Dielectric Loss-factor High Voltage Schering Bridge, High Voltage type tests of insulators, Impulse test of transformers as per relevant Indian standards.

References / Suggested Learning Resources:
1. High Voltage Engineering: Kuffel and Zaengl
2. High Voltage Measurement Techniques: A.J.Schwab

3. High Voltage Engineering: D.V. Razevig
4. High Voltage Engineering: Naidu & Kamaraju

MINI PROJECT

Course Code	PR EE 609
Course Title	Mini Project
Number of Credits	3 (L: 0, T: 0, P: 6)
Prerequisites	Nil
Course Category	Project (PR)
Number of classes	70 hours

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

CO Number	CO Description	K-level
CO-1	Demonstrate a through and systematic understanding of project contents	K2
CO-2	Identify the methodologies and professional way of documentation and communication	K3
CO-3	Illustrate the key stages in development of the project	K2
CO-4	Develop the skill of working in a Team	K3
CO-5	Apply the idea of mini project for developing systematic work plan in major project	K3

Course Content:-

The mini project topic should be selected / chosen to ensure the satisfaction of the urgent need to establish a direct link between education, national development and productivity and thus reduce the gap between the world of work and the world of study. The course should have the following-

1) Perform detailed study about various components of a project.
2) Study about methodologies and professional way of documentation and communication related to project work.
3) Develop idea about problem formulation.
4) Knowledge of how to organize, scope, plan, do and act within a project thesis.
5) Familiarity with specific tools (i.e. hardware equipment and software) relevant to the project selected.
6) Demonstrate the implementation of a mini project work.