Third Year Second Semester

Course code	**EE/PC/B/T/321**
Category	Program Core
Course title	Power System Performance
Scheme and Credits	L-T-P: 2-1-0; Credits: 3.0;
Pre-requisites (if any)	

EE/PC/B/T/321: Power System Performance	L	T
Basic concept of active and reactive power control of Synchronous generator. Interdependence of active power with frequency and reactive power with voltage and concept of decoupling.	2	1
Speed Governing System: Description of Speed Governor, Speed changer and main components of speed governing system, principle of operation.	2	0
Load frequency control: Representation of speed governing system, effect of governor droop on load sharing among generators, dependence of load on frequency, system inertia. Modeling and analysis of single area load-frequency control, supplementary control, concept of control area.	4	2
Power system stability: Steady state and transient stability, Swing equation and its numerical solution, equal area criterion for transient stability, improvement of transient stability.	5	1
Reactive power control: Role of excitation system, main & pilot exciters, description of different types of excitation systems.	2	0
Per-Unit representation of Power system– Selection of base quantities, percent and per unit values, advantage of per unit system.	2	1
AC Transmission – Power flow through a line, power circle diagram, line charts, active power flow and voltage control in transmission system. Line loadability and voltage dependence.	3	1
Power flow in interconnected systems and load flow analysis – Gauss –Seidel method.	4	1
Symmetrical fault analysis.	2	1
Elements of HVDC Power transmission	2	0
Economic operation of power plant – cost curves, heat rate, incremental rate, economic load sharing among generating units.	2	1

Reference Books:

1	Power System Analysis: J. J. Grainger & W. D. Stevenson, McGraw Hill
2	Power System Engineering: I. J. Nagrath & D. P. Kothari, Tata McGraw Hill
3	Electric Energy System Theory: O. I. Elgerd, Tata McGraw Hill
4	Elements of Power System Analysis: W. D. Stevenson, McGraw Hill.
5	Power System Analysis: A. R. Bergen & V. Vittal, Pearson Education

6	Power System Analysis Operation and Control: Chakrabarti & Halder, PHI Learning Pvt. Limited.
7	Electrical Power Systems: Ashfaq Husain, CBS Publishers & Distributors Pvt. Ltd.

Content Delivery Method

- Class Room lecture (Chalk and Board) (D1)
- Visual presentation (D2)
- Tutorial (D3)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Discuss** and explain per unit representation of Power System and power flow and voltage control of a transmission system. (K2)
CO2	**Analyse** Gauss-Siedel load flow and symmetrical fault. (K4)
CO3	**Describe** HVDC power transmission and economic operation of power plant. (K2)
CO4	**Illustrate** load frequency control. (K3)
CO5	**Illustrate** power system stability. (K3)
CO6	**Illustrate** Excitation systems and their various types used in generating stations. (K3)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Power System Performance	**CO1**	**3**			**1**											
	CO2	**2**	**3**													
	CO3	**3**														
	CO4	**2**	**3**													
	CO5	**2**	**3**													
	CO6	**2**	**3**													

Course code	**EE/PC/B/T/322**
Category	Program Core
Course title	High Voltage Engineering
Scheme and Credits	L-T-P: 2-1-0; Credits: 3.0;
Pre-requisites (if any)	

EE/PC/B/T/322: High Voltage Engineering	L	T
High voltage power transmission and distribution.	1	0
Insulators: Type of insulators and their applications, voltage distribution and string efficiency of disc insulators.	2	1
Corona: Theory of corona formation, corona loss and radio interference.	2	1
Overvoltage phenomena: Lightning and switching surges. Travelling waves: Reflection and refraction with respect to different type of line terminations.	2	1
Overvoltage protection: Grounding practice and over-voltage due to earth fault, lightning arresters and surge suppressors.	2	1
Insulation coordination scheme of open-air substation.	1	0
High voltage cables: Single core, belted, XLPE and gas-filled. Inter-sheath grading. Requirement of extra high voltage cables.	2	2
Bushings: Non-condenser and condenser bushings, field distribution.	1	1
Statistical Methods Generation of High AC Voltage –Testing transformer and its cascade connection, single-phase series resonance circuit	3	1
Generation of High DC Voltage –Single-stage and multi-stage symmetric as well as asymmetric voltage multiplier circuits	2	1
Generation of Impulse Voltage –Single-stage and multi-stage impulse generators circuits, Triggering and synchronization with CRO	2	2
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	2	2
Measurement of RMS value of high AC Voltage –Capacitive Voltage Transformer, Potential Dividers, Electrostatic Voltmeter	1	1
Measurement of High DC Voltage –Ammeter in series with high resistance	1	0
High Voltage type tests of insulators, Impulse test of transformers as per relevant Indian standards.	2	0

Reference Books:

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

Content Delivery Method	
- Class Room lecture (Chalk and Board) (D1) - Visual presentation (D2) - Tutorial (D3) - Discussion (D7)	
Course Outcomes:	
The students of the course should be able to	
CO1	**Describe** the advantages of High Voltage AC and DC Power Transmission (K2)
CO2	**Explain** various types of insulators, Cables and the importance of Insulation Co-ordination (K2)
CO3	**Analyse** the Corona phenomenon, categorise Grounding and Analyze Lightning & Switching Overvoltages (K4)
CO4	**Understand** the methods of Generation of High AC Voltage, Generation of High DC Voltage and Generation of Lightning Impulse Voltage (K2)
CO5	**Description** of the methods of High Voltage measurement (K2)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
High Voltage Engineering	**CO1**	**3**	**1**													
	CO2	**3**	**1**			**1**										
	CO3	**3**	**1**	**1**			**2**									
	CO4	**3**	**1**													
	CO5	**3**	**1**													

Course code	**EE/PC/B/T/323**
Category	Program Core
Course title	Electrical Utilization & Illumination
Scheme and Credits	L-T-P: 3-0-0; Credits: 3.0;
Pre-requisites (if any)	

EE/PC/B/T/323: Electrical Utilization & Illumination	L	T
Electric heating: Basic advantages, classification.	1	0
Resistance Heating: basic principles of direct and indirect heating types. Control of heating: Open Loop techniques: graded resistance, tapped inductor. Solid state control – SCR, on-off control, ac phase control, integral cycle control. Closed loop techniques: On-off, Proportional, PI and PID control. Properties and design of heating elements.	3	0
Electric Arc Heating: basic principles of direct and indirect heating types. 1-phase and 3-phaseAC and DC arc types. Their power supply system, requirement of reactor. Electric Arc Furnaces (EAF); Construction, principle of operation and relative advantages of direct and indirect Arc furnaces. Electrode Regulation system.	3	0
Induction Heating: basic principles and applications. Induction Furnaces: basic principles of coreless and core types and their power supply systems, choice of operating frequency.	3	0
Dielectric Heating: basic principles and applications.	1	0
Principle of Thermostat control for cooling.	1	0
Harmonic current generation due to non-linear loads. Effect of Harmonic currents on power supply system and its components. Power factor degradation and other effects of harmonics. Displacement Factor, Distortion Factor and Total Harmonic Distortion. Power line filters, Introduction to near-unity power factor rectifiers and Active Power Filters.	3	0
Storage Batteries: common types and their characteristics and applications. Principles of charging, modes of charging, eg., Constant current, constant voltage, tickle, float, boost, etc. Charge termination methods, common charger types. Temperature compensation of charging voltage. Battery size estimation.	4	0
Uninterruptible Power Supplies: Basic concepts, schemes, back-up, redundancy, transfer switch.	1	0
Light and electromagnetic radiation; light generation principles – incandescence, luminescence; sources of light-thermal radiator-blackbody radiator, laws of thermal radiation; daylight and artificial light, spectral power distribution (SPD) of light sources;	2	0
Radiometric and Photometric quantities, visual response curve of standard observer, relation between lumen and watt, photometric standards;	1	0
Laws of illumination, perfect diffuser, Lambert’s law; applications; simple problems;	2	0

Photometry-visual & physical photometry, Bench Photometer, Illuminance meter, Luminance meter	2	0
Distribution photometer, Computation of lumen output from Luminaire from luminous intensity distribution-zone factor, zonal lumen, Integrating Sphere.	2	0
Lamps-general classification, tungsten filament, tungsten halogen, FTL, CFL, HPSV, MH, LED -construction, principle of operation, features etc. lamp control gear-its function, electromagnetic and electronic type- principle of operation; electrical and photometric specifications of lamps;	2	0
Luminaire-its function and classification; applications	1	0
Elementary lighting design-design considerations, design parameters, BIS recommendation, indoor general lighting design by Lumen method.	2	0
Introduction to lighting control. Different lighting control strategies, Lighting Control Protocol	2	0
Concepts of energy efficient lighting design and payback calculation.	2	0
Human Factors in lighting.	1	0
Elements of Outdoor Lighting.	1	0

Reference Books:

1	Art & Science of Utilisation of Electrical Energy: H. Partab, Dhanpat Rai & Sons.
2	Storage Batteries: G. W. Vinal, John Wiley & Sons Inc.
3	Power Electronics: N. Mohan, T. M. Undeland & W. P. Robbins, John Wiley & Sons.
4	Power Electronics: P. C. Sen, Tata McGraw-Hill Publishing Co. Ltd.
5	Modern Power Electronics: P. C. Sen, Wheeler Publishing.
6	Thyristorised Power Controllers: G. K. Dubey, S. R. Doradla, A. Joshi & R. M. K. Sinha, Wiley Eastern Ltd.
7	Lamps and Lighting: Edited by J.R.Coaton and A.M.Marsden, 4th Edition.
8	Lighting for energy efficient luminous environments: Ronald N. Helms & M Clay Belcher.
9	Illumination Engineering: From Edison lamp to the LASER: J. B. Murdoch
10	Electric Discharge Lamps: John F. Waymouth.
11	Human Factors in Lighting: P. R. Boyce.
12	Lighting Control Hand book: Craig Dilovie.
13	Interior Lighting: Fundamentals, Technology and Application: W. J. M. van Bommel.
14	National Lighting Code 2010: Bureau of Indian Standard.
15	Applied Illumination Engineering: Jack L. Lindsey, Second Edition.
16	Road lighting: W. J. M. van Bommel & J. B. de Boer.
17	Lighting Engineering: Applied Calculations: R. H. Simons and Robert Bean.
18	Energy Management in Illumination Systems: Kao Chen.

Content Delivery Method

- Class Room lecture (Chalk and Board) (D1)
- Visual presentation (D2)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Recall** the concept of Electrical power and energy losses, and basic principles of Electro chemical cells, concepts of radiators, light as an electromagnetic wave, relating lumen to watt, fundamental terminologies of Illumination Engineering.(K1)
CO2	**Discuss** the construction and operation of power level filters, electrical furnaces, secondary batteries and uninterrupted power supplies, different light sources and there operating principles, Laws of Illumination Engineering, Photometry, different luminaires and control gear.(K2)
CO3	**Develop** over-all schematics of power level filters, electrical furnaces and uninterrupted power supplies, lighting equipment including lighting control scheme, lighting layout for Indoor lighting application. (K3)
CO4	**Compare** and **analyze** different types of power level filters, electrical furnaces, batteries, uninterrupted power supplies, different lighting equipment and different lighting design. (K4)
CO5	**Design**a complete lighting solution including advanced lighting control techniques with payback calculation for Indoor application. (K5)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Electrical Utilization & Illumination	**CO1**	**3**	**2**													
	CO2	**3**	**2**	**1**												
	CO3	**2**	**2**	**3**												
	CO4	**3**	**2**	**2**			**2**	**2**								
	CO5	**2**	**2**	**3**												

Course code	**EE/PC/B/T/324**
Category	Program Core
Course title	Electrical Drives
Scheme and Credits	L-T-P: 3-0-0; Credits: 3.0;
Pre-requisites (if any)	

EE/PC/B/T/324: Electrical Drives	L	T
Motor control components and Schemes : Contactors, relays, limit switches, etc. Motor control circuit like Start-Stop control, Star-Delta starter, Auto-Transformer starter, forward-reverse changeover.	3	0
Drive specifications and Basic terminology : Classification of Drives, Base speed, speed ratio, constant torque drive, constant HP drive, etc. Four quadrant representation.	2	0
Stability of Drives Systems : Dynamics of loading of motor with different types of mechanical load. Choice of couplings and bearings.	2	0
Thermal Characteristics : Heating and cooling of motors, operating duty cycles.	2	0
Dynamics of Starting : Starting transients, Acceleration time, energy loss in starting. Effect of flywheels.	2	0
Regeneration in Drives : Dynamic braking, regenerative braking, dc injection, plugging.	4	0
Electric Traction : General introduction and requirements, speed-time curve mechanics in train movement. DC and AC traction supplies. Current collectors. Traction motors.	4	0
Linear motors and magnetic levitation.	1	0
Basics of DC Motor Drives : 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.	5	0
Three Phase Induction Motor Drives : Solid state control of induction motors – basic principles. V/f control with constant fluxand field weakening. Simple modeling of an induction motor. Drive schemes withterminal voltage feedback and slip-compensation, also with tacho-feedback for bothconstant flux and field weakening.	5	0
Synchronous Motor Drives : Solid state control of synchronous motors – basic principles. V/f control with constant flux and field weakening. Simple modeling of a synchronous motor. Drive schemes with open loop and with position feedback.	3	0

Realisation of converters system for ac and dc drives : 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 Cyclo-converters. Basic operating principles and characteristics of the schemes.	3	0
Protection of Drives : Protection schemes for overall drive systems. Power electronic controlled starting of dc and ac motors	3	0

Reference Books:

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

Content Delivery Method

- Class Room lecture (Chalk and Board) (D1)
- Visual presentation (D2)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Interpret** the control circuits and power circuits of electric drives system (K2).
CO2	**Explain** the control mechanism of commonly used power electronic controllers used for drive systems, their maintenance, safety and potential costs (K2).
CO3	**Select** drive specifications and **comprehend** the importance of temperature rise and duty cycle (K3)
CO4	**Analyse** the transient characteristics of electric motors during starting and breaking (K3).
CO5	**Comprehend** the basics of electric traction system (K3).

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Electrical Drives	**CO1**	**3**	**2**	**1**				**1**					**1**			
	CO2	**1**	**3**	**1**				**1**					**1**			
	CO3	**1**	**2**	**3**				**1**					**1**			
	CO4	**1**	**2**	**1**	**3**			**1**					**1**			
	CO5	**1**	**3**	**2**				**1**					**1**			

Course code	**EE/PC/B/T/325**
Category	Program Core
Course title	Process Instrumentation and Control
Scheme and Credits	L-T-P: 2-1-0; Credits: 3.0;
Pre-requisites (if any)	

EE/PC/B/T/325: Process Instrumentation and Control	L	T
Introduction to process control loop and salient components. Process control terminology. Process instrument diagram. Self-regulating and non self-regulating processes.	2	1
Controller implementation. Electronic analog P, PI, PD, PID controllers. Pneumatic controllers: baffle-nozzle amplifiers, relay valve, pneumatic P, PI, PD, PID controllers.	3	1
Introduction to digital controllers. Concept of sampling. Digital P controller, digital PI controller employing rectangular and trapezoidal integration, digital PD controller employing backward difference algorithm, digital PID controller. Provision for anti-integral windup and anti-derivative kick. Auto/Manual modes of operation. Incremental form of PI/PID controller. Bumpless transfer. Design of controllers with auto-tuning method employing relay feedback.	4	2
Signal transmission systems in process control loop. Analog voltage/current transmission standards. Digital serial transmission standards: RS-232C, RS-422, RS-423, RS-485. Importance of transmission noise. MODEM based signal transmission.	1	1
Importance of time delay in process control loop. Practical examples. Smith predictors/controllers.	1	1
Final control elements in process control loop. Types of Actuators: Pneumatic, Electrical, Hydraulic. Positioners. Pneumo-electric converters. Linear and rotary actuators. Linear pneumatic actuators with and without positioners. Control valves: single stem and double stem sliding valves, butterfly valves, ball valves. Valve sizing. Methods of fluid control: variable delivery, bypass.	3	1
Concept of Processes and Units: Process statics, steady state operating point, mass and enthalpy balance.	1	0
Modeling of process dynamics: Modeling of simple Industrial processes. Standard first order process model with delay, time and frequency response of standard first order process model with delay.	4	1
Single loop control of standard first order process plants: P, PI, PD and PID control, Controller tuning, Frequency domain design, Ziegler-Nichol's and other empirical tuning methods.	3	2
Feed-forward control: Configurations, advantages, limitations and industrial applications.	1	1
Multi-loop and Cascade control: Configurations, interaction and decoupling,	1	1

industrial applications.		
Ratio control: Principles, configurations including cascade configuration.	1	1
Case study: Boiler Control.	2	0

Reference Books:

1	Principles and Practice of Automatic Process Control: Smith and Corripio
2	Principles of Process Control: Patranabis
3	Automatic Process Control: Eckmann
4	Process Control Systems: Shinskey
5	Process Systems Analysis and Control: Coughanowr & Koppel
6	Chemical Process Control: Stephanopoulos
7	Process Dynamics and Control: Dale E. Seborg, Thomas F. Edgar & Duncan A Mellichamp

Content Delivery Method

- Class room lecture (chalk and board) (D1)
- Visual presentation (D2)
- Tutorial (D3)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Describe** basic concepts of processes, process control loop and its salient components. (K1)
CO2	**Discuss** modeling of process dynamics and single-loop and multi-loop control of process plants. (K2)
CO3	**Develop** concepts for implementing electronic, pneumatic and digital P, PI, PID controllers, actuators, control valves and signal transmission systems.(K3)
CO4	**Analyze** constraints in implementation of controllers and their solutions. (K4)
CO5	**Design** controllers, actuators and control valves from theoretical and implementation perspective. (K5)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Process Instrume-ntation and Control	**CO1**	**3**	**2**	**1**												
	CO2	**3**	**2**	**1**						**1**						
	CO3	**2**	**2**	**3**	**2**			**1**								
	CO4	**2**	**2**	**2**	**3**			**1**								
	CO5	**2**	**2**	**3**	**2**	**2**	**2**	**1**	**1**	**2**						

Course code	**EE/PE/H/T/326**
Category	Program Elective
Course title	Honours Paper I (Basket-1)
Scheme and Credits	L-T-P: 3-1-0; Credits: 4.0;

Course code	**EE/PE/H/T/326A**
Category	Program Elective
Course title	Nonlinear and Optimal Control
Scheme and Credits	L-T-P: 3-1-0; Credits: 4.0;
Pre-requisites (if any)	

EE/PE/H/T/326A: Nonlinear And Optimal Control	L	T
Nonlinear Control Nonlinear Models and Nonlinear Phenomena, Examples of nonlinear systems, Pendulum, Mass-Spring System, Negative-Resistance Oscillator, , Common Nonlinearities, Some Common Nonlinear System Behaviors; Lipchitz condition	4	1
Nonlinear System Analysis: Concepts of Phase Plane Analysis, Phase Portraits, Singular Points, Symmetry in Phase Plane Portraits, Construction of Phase Portraits, Phase Plane Analysis of Linear and Nonlinear Systems, Existence of Limit Cycles;	4	2
Describing function Fundamentals, computation of Describing Functions, describing function analysis of Common Nonlinearities, the Nyquist Criterion and Its extension, existence of Limit Cycles, Stability of Limit Cycles, Reliability of Describing Function Analysis.	3	2
Stability Analysis of Nonlinear Systems: Lyapunov's First Method, Lyapunov's Second Method, Lyapunov Analysis of Linear and Nonlinear Systems, Concepts of Stability for Autonomous and Non-Autonomous Systems	5	1
Nonlinear Control System Design: Control Design Based on Lyapunov's Method, Feedback Linearization, Backstepping, Variable Structure Control with Overview of Sliding Control.	3	2
Optimal Control Introduction to Optimal Control, Formulation of Optimal Control Problem, Characteristics of Plant, Minimum-Time Problem, Minimum-Energy Problem, Minimum-Fuel Problem, State Regulator Problem, Output Regulator Problem, Tracking Problem and Overview of Calculus of Variations.	3	1
Minimization of Functions, Minimization of Functionals, Overview of some Computing Tools: Steepest Descent Method, Fletcher-Powell Method.	3	2
The Regulator Problem: Review of Regulator Problem, The Hamilton-Jacobi Equation, Discrete-Time Linear State Regulator, Continuous-Time Linear State Regulator, Time-Invariant Linear State Regulator, Numerical Solution of Riccati Equation, Linear Regulator with a Prescribed Degree of Stability, Quadratic Weight Selection for Single Input System. Tracking Control Scheme: The Problem of Achieving a Desired Trajectory, Finite-Time Results, Infinite-Time Results.	5	2
Properties of Regulator Systems with a Classical Control Interpretation: The Regulator from an Engineering Viewpoint, Some Classical Control Ideas: Sensitivity, Complementary	4	2

Sensitivity, and Robustness, Gain Margin, Phase Margin, and Time-Delay Tolerance, Insertion of Nonlinearities, Overview of The Inverse Optimal Control Problem.	2	1

Reference Books:

1	Applied Nonlinear Control: J. E. Slotine & W. Li, PH International.
2	Nonlinear Systems: H. K. Khalil, PH.
3	Modern Control System Theory: M. Gopal, Wiley Eastern Limited.
4	Optimal Control theory – An Introduction: Donald E. Kirk.
5	Systems and Control: Stanislaw H. Zak.
6	Optimal Control: Linear Quadratic Methods: Brian D. O. Anderson and John B. Moore, PH.
7	Nonlinear Systems Analysis: M. Vidyasagar
8	Non-linear Systems Analysis Stability and Control: Shankar Sastry.
9	Nonlinear Systems: H. K. Khalil, PH
10	Control System Engineering: Nagrath and Gopal.

Content Delivery Method

- Class Room lecture (Chalk and Board) (D1)
- Visual presentation (D2)
- Tutorial (D3)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Identify** different types of nonlinearities and nonlinear systems, **Interpret** formulation of Optimal Control Problems, **Restate** Calculus of Variations (K2).
CO2	**Construct** Phase portraits, **Sketch** Describing Functions for Common Nonlinearities, **Interpret** the concept of minimization of Functions and Functionals (K3).
CO3	**Investigate** the Stability of Nonlinear Systems through Lyapunov's and Popov's methods for Autonomous and Non-Autonomous Systems (K4).
CO4	**Investigate** the Regulator and Tracking Problems, **Solve** Riccati Equation (K4).
CO5	**Synthesis of** nonlinear systems with Feedback linearization, backstepping and variable structure design methods (K5).
CO6	**Appraise** the concepts of Sensitivity, Complementary Sensitivity and Robustness and **Formulate** the Inverse Optimal Control Problems (K5).

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Nonlinear and Optimal Control	**CO1**	**3**	**2**	**1**		**1**					**1**		**1**			**3**
	CO2	**3**	**2**	**2**	**1**	**2**					**1**		**1**			**3**
	CO3	**3**	**2**	**2**	**2**	**2**							**1**			**3**
	CO4	**3**	**2**	**2**	**1**	**2**		**1**		**1**		**1**	**1**			**3**

	CO5	**3**	**2**	**2**	**1**	**2**		**1**					**1**			**3**
	CO6	**3**	**2**	**2**	**1**	**2**		**1**		**1**	**1**	**1**	**2**			**3**

Course code	**EE/PE/H/T/326B**
Category	Program Elective
Course title	Condition Monitoring of Electrical Systems
Scheme and Credits	L-T-P: 3-1-0; Credits: 4.0;
Pre-requisites (if any)	

EE/PE/H/T/326B: Condition Monitoring of Electrical Systems	L	T
Introduction to condition monitoring, understanding the role of insulation in equipment, introduction to different types of diagnostic tests.	3	1
Insulation resistance- measurement, interpretation, tests, involvement of different factors, practical applications and working formulas.	2	1
Dielectric testing- materials, theory of dielectric breakdown, leakage current and dielectric current, objective of dielectric testing, false failure, a.c. vs. d.c. testing.	2	1
Common testing techniques, polarization index test, dielectric absorption test, HiPot test, step voltage test, surge test.	2	1
Conventional diagnostic techniques in transformers- dissolved gas analysis, degree of polymerization, furan in oil -analysis.	3	1
Time domain dielectric response measurements- polarization and depolarization current measurements, concept of recovery voltage.	3	2
Frequency domain spectroscopy. Advantages and limitations of dielectric response measurements in time-domain and frequency-domain.	1	1
Switchgear monitoring- introduction, monitored parameters, current developments in techniques, assistance in maintenance scheduling and cost analysis.	2	0
Introduction to condition monitoring of rotating machine: The need for monitoring ; What and when to monitor	1	0
Construction, operation and failure modes of electrical machines: Construction of electrical machines; material used; Structure of electrical machines and their types; Insulation aging, insulation failure, other failure	3	1
Reliability of machines and typical failure rates: Root causes; Reliability analysis; Typical failure rates and MTBFs	3	1
Instrumentation requirements	1	1
Signal processing requirements	1	1
Temperature monitoring	1	1
Chemical monitoring	1	1
Vibration monitoring	1	1
Electrical techniques: current, flux and power monitoring	3	1
Electrical techniques: discharge monitoring	2	0
Application of artificial intelligence techniques	1	0

Reference Books:

1 Condition Monitoring of Rotating Electrical Machines: Peter Tavner, Li Ran, Jin man & Haward Shedding

2 Hand Book of Condition Monitoring: B. K. N. Rao

3 Hand Book of Condition Monitoring Techniques and Methodology: A Davis.

4 Recent Trends in the Condition Monitoring of Transformers, Theory, Implementation and Analysis: Sivaji Chakravorti, Debangshu Dey, Biswendu Chatterjee, Springer, London.

Content Delivery Method

- Class Room lecture (Chalk and Board) (D1)
- Visual presentation (D2)
- Tutorial (D3)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Identify** the electrical techniques in condition monitoring of equipments (K2).
CO2	**Explain** the methods of plant condition monitoring, their maintenance, safety and potential costs (K2).
CO3	**Apply** maintenance strategy suitable for particular equipment/system (K3).
CO4	**Illustrate** the basic insulation diagnostic tests (K3).
CO5	**Analyse** the methods of condition monitoring used in rotating machines, transformers and switchgears (K4).

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Condition Monitoring of Electrical System	**CO1**	3	2	1				1								3
	CO2	1	3	1				1								3
	CO3	1	3	1				1								3
	CO4	1	2	1	3			1								3
	CO5	1	1	2	3			1					1			3

Course code	**EE/PE/H/T/327**
Category	Program Elective
Course title	Honours Paper II (Basket-2)
Scheme and Credits	L-T-P: 3-1-0; Credits: 4.0;

Course code	**EE/PE/H/T/327A**
Category	Program Elective
Course title	Bio-Medical Instrumentation
Scheme and Credits	L-T-P: 3-1-0; Credits: 4.0;
Pre-requisites (if any)	

EE/PE/H/T/327A: Bio-Medical Instrumentation	L	T
Components of Man-Instrument system	2	0
Measurement of Electrical potentials and Magnetic Fields from the Body surface Electrodes; Half-Cell Potential; Equivalent Circuits	3	1
Biopotential amplifiers; Medical isolation amplifiers; Driven-Leg ECG amplifiers	3	2
The ECG: Electrode placement; Vectorcardiography; Feature extraction	4	1
The EMG	2	1
The EEG; Event related potentials, Other body surface potentials;	2	0
EOG; Electroretinogram	2	0
Stimulation of excitable tissues; Cardiac pacing and defibrillation	2	0
Heart-lung machine	1	0
Dialyzer	1	0
Sensors commonly encountered in biomedical applications	4	1
Pressure measurements – blood pressure measurements Electro-chemical sensors – noninvasive blood gas sensing with electrodes Optical sensors – Pulse Oximetry	4	2
Plethysmography; volume displacement; impedance, Pulmonary Function Tests Ultrasound - Doppler US for blood and tissue velocity measurements Digital Interfaces in measurement systems Patient care monitoring unit Networking Medical Transcription Internet based monitoring	3	1
Tomographic Techniques: a)X-Ray/ CT scan b) MRI c) Beta-gamma scanning	2	1
Bioelectric Signal Processing; Biotelemetry Bioelectric Signal Processing tools, their applicability, data handling and data reduction methods.	4	3
Reference Books:		

1	Medical Instrumentation: Application and Design: John G. Webster, Editor
2	Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation: Robert B. Northrop
3	Biomedical Instrumentation and Measurements: L. Cromwell, F. J. Weibell, E. A. Pfeiffer
4	Design and Development of Medical Electronic Instrumentation: David Prutchi, Michael Norris

Content Delivery Method

- Class room lecture (chalk and board) (D1)
- Visual presentation (D2)
- Tutorial (D3)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Describe** the measurement procedure of various physiological parameters related to biomedical instrumentation. (K1)
CO2	**Explain** the origins of various bioelectric potentials and operating principles of bio-potential amplifiers. (K2)
CO3	**Illustrate** methodologies for acquisition and processing of various biomedical signals. (K3)
CO4	**Investigate** the suitability of a bioinstrumentation system to various physiological events. (K4)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Bio-Medical Instrumentation	**CO1**	**3**	**1**													**3**
	CO2	**3**	**2**	**1**												**3**
	CO3	**2**	**3**	**1**	**2**	**2**										**3**
	CO4	**1**	**2**	**1**	**3**	**2**	**1**									**3**

Course code	**EE/PE/H/T/327B**
Category	Program Elective
Course title	Energy Systems
Scheme and Credits	L-T-P: 3-1-0; Credits: 4.0;
Pre-requisites (if any)	

EE/PE/H/T/327B: Energy Systems	L	T
Energy Resources in general, present scenario, Energy consumption and acts, Environmental aspects of Thermal, Nuclear and hydroelectric power generation.	5	1
Types of emission from various sectors, co-relation between emission & pollution. Kyoto protocol, and carbon credit etc.	3	1
Energy audit: primary and detail auditing. Energy management: Demand side management (DSM) and Supply side management (SSM), Supply side management through energy price control.	6	2
Smart Grid – functions, features and technologies. The role of Reactive power management. Distributed generation (DG) and Micro grids: - features of distributed generations, technical issues of DG connection at distribution voltage level. Composition of Micro grid.	5	2
Renewable energy resources: Solar- solar thermal, solar PV	3	1
Wind energy- prospects and status in national and global context, principles of wind energy conversion, wind monitoring system, VAWT and HAWT, selection of site for WTGS.	4	2
Geothermal, Tidal, Bioenergy- Biomass and bio gas with gasifiers etc.	3	1
Fuel cell. Mini and micro hydel power plant, micro turbine.	4	2
Energy storage and conservation:- Types and methods of energy storage, Energy storage setups like Chemical, Thermal, Magnetic, fly wheel storage etc. Energy conservation - Concept of co-generation, combined heat and power (CHP).	5	2

Reference Books:

1. Energy Management Handbook: Wayne C. Turner & Steve Doty, 6th Ed., The Fairmont Press, Inc.
2. Guide to energy management: Barney L. Capehart, Wayne C. Turner, William J. Kennedy, 6th Ed., The Fairmont Press, Inc.
3. Power Station Engineering and Economics: Skortzki, B. G. A. and Vopat W. A., McGraw Hill, New York.
4. Solar Energy Engineering: Sayigh A. A. M, Academic Press.
5. Demand Side Management Planning: Gelling C. W. et al, The Fairmount Press, Lilbum, USA
6. Generation of Electrical Energy: B. R. Gupta, Eurasia Publishing House (Pvt.) Ltd.
7. Non-Conventional Energy Resources: Prof. D. S. Chauhan and Prof. S. K. Srivastava, New Age International (P) Ltd.

Content Delivery Method

- Class Room lecture (Chalk and Board) (D1)
- Visual presentation (D2)
- Tutorial (D3)
- Discussion (D7)

Course Outcomes:

The students of the course should be able to

CO1	**Assess** the environmental aspects of conventional power generation. (K1)
CO2	**Describe/ discuss** the principles of power generation from renewable sources. (K2)
CO3	**Explain** the concept of energy management and energy audit. (K2)
CO4	**Identify** the energy scenario and identify the principles of energy conservation and energy storage devices. (K2)
CO5	**Identify** the features of smart grid and distributed power generation. (K2)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Energy Systems	**CO1**						**2**	**3**	**1**							**3**
	CO2	**3**	**1**													**3**
	CO3						**3**					**2**	**1**			**3**
	CO4	**2**					**3**	**2**								**3**
	CO5	**1**		**3**				**2**								**3**

Course code	**EE/PC/B/S/321**
Category	Program Core
Course title	Electrical Engineering Laboratory - IV
Scheme and Credits	L-T-P: 0-0-3; Credits: 1.5;
Pre-requisites (if any)	

EE/PC/B/S/321: Electrical Engineering Laboratory - IV	P
1. Starting and performance of single phase induction motor.	3
2. Calibration of a 3-phase Watt-Hour meter.	3
3. Study of DC Servo Motor characteristics.	3
4. Measurement of generalized constant (A, B, C, D) of a long transmission line.	3
5. Measurement of high AC voltage by sphere gap and peak voltmeter.	3
6. Calibration of Lux meter and measurement of horizontal intensity distribution from a lamp with the calibrated Lux meter.	3
7. Study of 3- phase transformer connections.	3
8. Measurement of temperature.	3
9. Study of on-off control system.	3
10. Study of power transfer through a transmission system.	3
11. Study and dry power frequency flashover test on 11kV porcelain pin insulator	3
Arrear, Laboratory Examination	6

Content Delivery Method

- Class room lectures (Chalk and Board) (D1)
- Active learning (D4)
- Blended/Hybrid learning (D5)
- Discussions (D7)
- Case Studies (D9)

Course Outcomes:

The students of the course should be able to

CO1	**Identify** the instruments required to perform the experiment (K1, S1)
CO2	**Select** the range/ratings of the instruments identified (K2, S1)
CO3	**Comprehend** the objective of the experiment and **Relate** that with the acquired theoretical knowledge (K3, S2)
CO4	**Develop** the circuit duly connecting selected instruments and other devices (K2, S2)
CO5	**Interpret** the data and prepare a detailed report. (K2, S2)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Electrical Engineering Laboratory - IV	**CO1**	**3**	**2**	**1**						**2**				**3**		
	CO2	**1**	**3**	**2**						**2**				**3**		
	CO3	**1**	**3**	**2**						**2**				**3**		
	CO4	**1**	**2**	**3**						**2**				**3**		
	CO5	**1**	**1**	**2**	**3**				**1**	**2**		**1**	**1**	**3**		

Course code	**EE/PS/B/S/322**
Category	Program Sessional
Course title	Power Electronics Design & Laboratory
Scheme and Credits	L-T-P: 0-0-3; Credits: 1.5;
Pre-requisites (if any)	

EE/PS/B/S/322: Power Electronics Design & Laboratory	P
1. Design of 1-phase and 3-phase rectifiers and inverters.	6
2. Design of choppers, dc/dc converters and ac phase controllers.	9
3. Design of related magnetic and filter circuits.	3
4. Design of relay and servo stabilizers.	3
5. Design of the control hardware and software for power electronic circuits.	3
6. Design of interface between control and power section.	3
7. Application of SPICE, MATLAB or other simulation software to power electronic circuit simulation.	12

Content Delivery Method

- Class room lectures (Chalk and Board) (D1)
- Active learning (D4)
- Blended/Hybrid learning (D5)
- Discussions (D7)
- Case Studies (D9)

Course Outcomes:

The students of the course should be able to

CO1	**Relate** and apply acquired knowledge of power electronics to identify a given problem (K1, S1)
CO2	**Select** different components and their ratings for appropriate circuit design (K2, S1)
CO3	**Develop** the circuits after duly connecting the selected components (K2,S2)
CO4	**Assess** the performance of the designed circuit using SPICE, MATLAB and other simulation software (K6, S3)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Power Electronics Design And Laboratory	**CO1**	3	2	1						2						
	CO2	1	2	3						2						
	CO3	1	1	2	3					2						
	CO4	2	1	1	1	3		1		2						

Course code	**EE/PS/B/S/323**
Category	Program Sessional
Course title	Power System Design
Scheme and Credits	L-T-P: 0-0-2; Credits: 1.0;
Pre-requisites (if any)	

EE/PS/B/S/323: Power System Design	P
Solving problems of power transmission and distribution systems.	39

Content Delivery Method

- Class room lectures (Chalk and Board) (D1)
- Active learning (D4)
- Blended/Hybrid learning (D5)
- Discussions (D7)
- Case Studies (D9)

Course Outcomes:

The students of the course should be able to

CO1	**Recall** the knowledge of distribution system design. (K1, S1)
CO2	**Categorise** the Low Tension (L.T.) and High Tension (H.T.) load of the given distribution system. (K5, S2)
CO3	**Recommend** the L.T. and H.T. transformer size. (K6)
CO4	**Determine** the location of L.T. and H.T. transformers and size of conductors. (K4, S1)
CO5	**Calculate** the efficiencies of transformers and distributors. (K3)
CO6	**Summarize** the design problem and its solution as a report. (K6, S1)

CO-PO Mapping(3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
Power System Design	**CO1**	**3**														
	CO2		**3**							**2**						
	CO3	**3**	**2**													
	CO4	**3**														
	CO5	**3**														
	CO6	**2**	**2**							**3**						

Course code	**EE/PC/B/S/324**
Category	Program Core
Course title	Microprocessor & Microcontroller Laboratory
Scheme and Credits	L-T-P: 0-0-3; Credits: 1.5;
Pre-requisites (if any)	

EE/PC/B/S/324: Microprocessor & Microcontroller Laboratory	P
Hand on experience with different microprocessor and microcontroller systems and their interfaces.	39

Content Delivery Method

- Class room lectures (Chalk and Board) (D1)
- Active learning (D4)
- Blended/Hybrid learning (D5)
- Discussions (D7)
- Case Studies (D9)

Course Outcomes:

The students of the course should be able to

CO1	**Relate** and **follow** the knowledge acquired on architectures of processors along with the organization of memories and peripherals along with the boards of processors. (K1, S1)
CO2	**Translate** the requirements of problems into a sequence of tasks as well as steps of assembly language programming and consequently **operate** the system accordingly. (K2, S2)
CO3	**Develop** appropriate programs to solve problems related to computation, sorting and presentation of data and **show** the result of execution of the program. (K3, S3)
CO4	**Arrange** various subprograms and subsystems using the concept of modular programming and **integrate** them to solve problems with the complexity of higher hierarchical level. (K4, S4)
CO5	**Plan** a processor-based system and **represent** it with interconnectivities of appropriate modules in a direction to achieve the targeted result. (K5, S5)

CO-PO Mapping (3 – Strong, 2 – Moderate and 1 – Weak)

		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Microprocessor & Microcontroller Laboratory	**CO1**	3	1													
	CO2	3	1													
	CO3	2	3	2	1											
	CO4	1	2	3	1											
	CO5	1	2	2	3	2										