Jharkhand University of Technology, Ranchi

Detailed Syllabus

6th Semester

Department of Electrical Engineering

Course structure of Electrical Engineering

Semester -6th
Branch: Electrical Engineering

S.No	Course Code	Subject	L	T	P	Credit
01	EE601	Power Systems-II	4	1	0	4
02	EE602	Power Electronics	3	1	0	3
03	EE603	Advanced Control Systems	3	1	0	3
04		Professional Elective-II	3	1	0	3
05		Open Elective-II	3	1	0	3
06						
	Laboratory/ Sessional					
01	EE601P	Power System-II Lab	0	0	3	1
02	EE602P	Power Electronics Lab	0	0	3	1
03	EE603P	Simulation Lab	0	0	3	1
04	EE604P	Electrical Workshop	0	0	3	1
05		Internship/Tour & Training/Industrial Training	0	0	3	2
Total credit						22

Professional Elective-II	
EE611	Electrical Estimation and Costing
EE612	Electrical Engineering Materials
EE613	Power System Restructuring
EE614	Green Energy Technology

Open Elective-II	
EE621	Advanced Control Systems*
EE622	Soft Computing Techniques
EE623	Power Electronics*
EE624	Mine Electrical Engineering*
EE625	Green Energy Technology*
Any paper floated by the other department can be selected/ opted by the Electrical Engineering Students	

***This course is not offered to Electrical Engineering students.**

Professional Core

EE601 **Power Systems-II**

L	T	Credit
4	1	4

Course Outcomes:

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

CO's	CO Description
CO1	**Illustrate** power system components using single line diagram and usage of per unit system.
CO2	**Calculate** symmetrical components and examine different types of faults (both symmetrical and unsymmetrical).
CO3	**Formulate** nodal admittance (Y-bus) matrix, and **develop** load flow equations and **find** its solution.
CO4	**Calculate** optimal generator allocations and analyze single area power system for load frequency control
CO5	**Illustrate** the concept of stability, power angle curve, and swing equation and diagnose steady-state and transient stability of the power system.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										
CO2	3	2	1	2								
CO3	3	3	1	3								1
CO4	3	3	1	2								1
CO5	3	3	1	3	2							1
Avg.	**3**	**2.6**	**1**	**2.5**	**2**							**1**

DETAILED SYLLABUS

Module I: Per Unit System **(4 lectures)**

Per Unit meaning and its calculation. Need and advantages of per unit system, Single line diagram, Per unit representation of a given power system network, Change of base value Impedance diagram, Numerical problems

Module II: Faults Analysis: **(8 lectures)**

Symmetrical fault Analysis: Short Circuit Current and MVA Calculations, Fault levels, Reactors-Numerical Problems. Symmetrical Component Theory: Symmetrical Component Transformation, Sequence Networks: Positive, Negative and Zero sequence Networks for transformers, transmission line and synchronous machine, Numerical Problems. Unsymmetrical Fault Analysis: LG, LL, LLG faults, Interconnection of sequence networks, effect of fault impedance, Numerical Problems

Module III: Load Flow Analysis **(8 lectures)**

Bus classification, formulation of Ybus matrix, power flow equations. Gauss – Seidel method, algorithm, derivation of iterative equation, modification for PV bus, Advantages and disadvantages, acceleration factor, Numerical Problems, Newton – Raphson method, algorithm, power mismatch vector, size of Jacobian matrix and its elements. Advantages and disadvantages, Numerical Problems, FDLF.

Module IV: Economic Operation of Power Systems **(6 lectures)**

Input-output characteristics of thermal and hydro plants, Optimum generator allocations without and with transmission losses, calculation of penalty factors, incremental transmission loss, transmission loss coefficients and their calculations.

Module V: Load Frequency Control **(8 lectures)**

Necessity of keeping frequency constant, Modeling of speed governing, steam turbine and generator, Definition of Control area, Block diagram representation of an isolated power system, Steady state analysis, Dynamic response, Proportional plus Integral control of single area and its block diagram representation, , Two area system, block diagram, Tie-line-bias control.

Module VI: Stability **(8 lectures)**

Concept of stability and Classification, Description of Steady State Stability Power Limit, Transfer Reactance, Synchronizing Power Coefficient, Power Angle Curve and Determination of Steady State Stability, Methods to improve steady state stability. Derivation of Swing Equation, Determination of Transient Stability by Equal Area Criterion, Application of Equal Area Criterion, Critical Clearing Angle Calculation.

Suggested Readings:

[1]. J Grainger and W.D. Stevenson , " Power System Analysis '' , McGraw Hill Education , First Edition, 2017

[2]. Hadi Sadat, "Power System Analysis", PSA Publishing LLC, Third Edition, 2011

[3]. D.P. Kothari and I.J. Nagrath, " Modern Power System Analysis '' ,McGraw Hill Education 2003

Reference Books:

[1]. Prabha Kundur, "Power System Stability and Control", McGraw Hill Education; First Edition, 2006.

[2]. A.J. Wood and B.F. Wollenberg, "Power Generation, Operation and Control", John Wiley and Sons, 2011.

EE602 **Power Electronics**

L	T	Credit
3	1	3

Course Outcomes:

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

CO's	CO Description
CO1	To **understand** different power semiconductor devices and their characteristics.
CO2	To **understand** the operation, characteristics and performance parameters of AC to DC Converters.
CO3	To **study** the operation and basic topologies of DC-DC Converters
CO4	To learn the different modulation techniques of PWM inverters and to **understand** commutation techniques.
CO5	To **study** the operation of AC voltage controller and it's various configurations.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2	1		1					1
CO2	2	2	3	3	2		1					1
CO3	2	2	3	2	1	1	1					1
CO4	2	3	2	2	2	1	1					1
CO5	2	3	3	2	1	1	1					1
Avg.	**2.2**	**2.4**	**2.6**	**2.2**	**1.4**	**1**	**1**					**1**

DETAILED SYLLABUS

Module I: Power Semiconductor Devices (10 Lectures)

Power Diode, BJT, MOSFET, IGBT, Thyristor, and GTO: constructional features, I-V Characteristics, switching Characteristics, Firing circuit for thyristor; protection of thyristor and gate drive circuit, Turn on techniques, Voltage and current commutation of a Thyristor.

Module II: AC-DC Converters (8 Lectures)

Introduction, Single-phase half-wave and full-wave rectifiers with R, R-L and R-L-E load; effect of source inductance, Three-phase full-bridge rectifier with R, R-L and R-L-E load; freewheeling effect, power factor improvement.

Module III: DC-DC Buck and Boost Converter (6 Lectures)

Introduction, Elementary chopper with an active switch and diode, concepts of duty ratio and average voltage, quadrant operation of chopper. Power circuit of a buck, boost and buck-boost converter, analysis and waveforms at steady state, duty ratio control of output voltage.

Module IV: Single-Phase Voltage Source Inverter (6 Lectures)

Introduction, Single-phase voltage source inverter, operation and analysis, concept of average voltage over a switching cycle, sinusoidal pulse width modulation, modulation index and output voltage. Current source inverter.

Module V: Three-Phase Voltage Source Inverter (6 Lectures)

Three-phase voltage source inverter, operation and analysis, 120- degree conduction, 180-degree conduction, three-phase sinusoidal pulse width modulation.

Module VI: AC Voltage Controllers (6 Lectures)

Introduction, principle of on-off control, principle of phase control and integral cycle control, configuration of three phase controllers, Cycloconvertor.

Suggested Readings:

[1]. M. H. Rashid, "Power electronics: circuits, devices, and applications", Pearson Education India, 2009.

[2]. N. Mohan and T. M. Undeland, "Power Electronics: Converters, Applications and Design", John Wiley & Sons, 2007.

[3]. R. W. Erickson and D. Maksimovic, "Fundamentals of Power Electronics", Springer Science &Business Media, 2007.

[4]. L. Umanand, "Power Electronics: Essentials and Applications", Wiley India, 2009.

EE603 **Advanced Control Systems**

L	T	Credit
3	1	3

Course Outcomes:

After successful completion of the course, students should be able to:

CO's	CO Description
CO1	**Evaluate** the output of a digital system for a given input.
CO2	**Describe** the dynamics of a Linear, Time Invariant systems through difference equations.
CO3	**Analyze** digital systems using the Z-transformation, state space methods.
CO4	**Design** digital controllers for physical systems.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2		1	1	1	1					1
CO2	3	1	3	2	2							
CO3	3	2		2	2							
CO4	3	3	3	3	3		1					2
Avg.	**3**	**2**	**3**	**2**	**2**	**1**	**1**					**1.5**

DETAILED SYLLABUS

Module I: Sampling and Reconstruction (8 Lectures)

Introduction to digital control system, Examples of Data control systems, Sampler, Sampling Theorem, Data Reconstruction: Digital to Analog conversion and Analog to Digital conversion, sample and hold operations.

Module II: Modeling discrete-time systems by pulse transfer function (8 Lectures)

Revisiting Z-transform: Introduction to Z – transforms, Theorems of Z – Transforms, inverse Z-transforms, Z-Transform method for solving difference equations. Mapping of S-plane to Z-plane, Pulse transfer function, Pulse transfer function of closed loop system, sampled signal flow graph

Module III: State Space Analysis (12 Lectures)

State variables, State model for linear continuous-time system. Types of state models, Eigen value and Eigen vectors, Solution of state equation, State transition matrix and its Properties.

Discrete state space model: Introduction to state variable model, various canonical forms, Characteristic equation, state transition matrix, Solution to discrete state equation.

Module IV: Controllability, Observability & Stability (8 Lectures)

Concepts of Controllability and Observability, Tests for controllability and Observability Duality between Controllability and Observability. Stability analysis of discrete time systems: Jury stability

test Stability analysis using Bi-linear transformation.

Module V: State Feedback Controller (6 Lectures)

Design of state feedback controller through pole placement – Necessary and sufficient conditions. Observer: Full Order Observer, Reduced Order Observer. Lyapunov Stability Theorem.

Suggested Readings:

[1]. Discrete-Time Control systems – K. Ogata, Pearson Education/PHI, 2nd Edition

[2]. B. C Kuo, Digital Control Systems, 2nd Edition, Oxford University Press, Inc., 1992.

Reference Books:

[1]. F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems, Addison-Wesley Longman, Inc., Menlo Park, CA , 1998.

[2]. Digital Control and State Variable Methods by M.Gopal, TMH.

Professional Elective-II
(Any One)

EE611 **Electrical Estimation & Costing**

L	T	Credit
3	1	3

Course Outcomes:

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

CO's	CO Description
CO1	**Understand** the purpose of estimation and costing.
CO2	**Understand** distribution of energy in a building, wiring and methods of wiring, cables used in internal wiring, wiring accessories and fittings, fuses and types of fuses..
CO3	**Analyze** design of lighting points and its number, total load, sub-circuits, size of conductor.
CO4	**Understand** types of service mains and estimation of service mains and power circuits.
CO5	**Estimate** overhead transmission and distribution systems and its components.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12
CO1	3	3	3	2	1	1						2
CO2	3	3	3	2	1	1						2
CO3	3	3	3	2	1	1						2
CO4	3	3	3	2	1	1						2
CO5	3	3	3	2	1	1						2
Avg.	**3**	**3**	**3**	**2**	**1**	**1**						**2**

DETAILED SYLLABUS

Module I: Principles of Estimation **(5 Lectures)**

Introduction to estimation & costing, Electrical Schedule, Catalogues, Market Survey and source selection, Recording of estimates, Determination of required quantity of material, Labor conditions, Determination of cost material and labour,Contingencies, Overhead charges, Profit, Purchase system, Purchase enquiry and selection of appropriate purchase mode, Comparative statement, Purchase orders, Payment of bills, Tender form, General idea about IE rule, Indian Electricity Act and major applicable I.E rules.

Module II: Residential Building Electrification **(7 Lectures)**

Introduction to electrical symbols, their advantages and requirement. Concept of wiring diagram, schematic diagrams and their types. General Rules guidelines for wiring of residential installation and positioning of equipments, Principles of circuit design in lighting and power circuits Procedures for designing the circuits and deciding the number of circuits, Method of drawing single line diagram. Selection of type of wiring and rating of wires and cables Load calculations and selection of size of conductor, Selection of rating of main switch Distribution board, protective switchgear ELCB and MCB and wiring accessories, Earthing of residential Installation, sequence to be followed for preparing estimate, Preparation of detailed estimates and costing of residential

installation.

Module III: Electrification of Commercial Installation (7 Lectures)

Concept of commercial installation, Differentiate between electrification of residential and commercial installation, Fundamental considerations for planning of an electrical installation system for commercial building, Design considerations of electrical installation system for commercial building, Load calculation and selection of size of service connection and nature of supply, Deciding the size of the cables, busbar and bus bar chambers, Mounting arrangements and positioning of switchboards, distribution boards main switch etc, Earthing of the electrical installation, Selection of type wire, wiring system and layout, Sequence to be followed to prepare estimate, Preparation of detailed estimate and costing of commercial installation.

Module IV: Service Connection, Inspection and Testing of Installation (7 Lectures)

Concept of service connection, Types of service connection and their features, Method of installation of service connection, Estimates of underground and overhead service connections, Inspection of internal wiring installations, Inspection of new installations, testing of installations, testing of wiring installations, Reason for excess recording of energy consumption by energy meter.

Electrical Installation For Power Circuits: Introduction, Important considerations regarding motor installation wiring, Determination of input power, Determination of input current to motors Determination of rating of cables

Determination of rating of fuse, Determination of size of Condit, distribution Board main switch and starter.

Module V: Design & Estimation of Overhead Transmission & Distribution Lines (10 Lectures)

Introduction, Typical AC electrical power system, Main components of overhead lines, Line supports, Factors governing height of pole, Conductor materials, Determination of size of conductor for overhead transmission line, Cross arms, Pole brackets and clamps,Guys and Stays, Conductors configuration spacing and clearances, Span lengths, Overhead line insulators, Insulator materials, Types of insulators, Lightning Arrestors, Phase plates, Danger plates, Anti climbing devices, Bird guards, Beads of jumpers, Muffs, Points to be considered at the time of erection of overhead lines, Erection of supports, Setting of stays, Fixing of cross arms, Fixing of insulators, Conductor erection, Repairing and jointing of conductor , Dead end clamps, Positioning of conductors and attachment to insulators, Jumpers, Tee-offs, Earthing of transmission lines, Guarding of overhead lines, Clearances of conductor from ground, Spacing between conductors, Testing and commissioning of overhead distribution lines, Some important specifications.

Module VI: Design and Estimation of Substations (6 Lectures)

Introduction, Classification of substation, Indoor substations, Outdoor substations, Selection and

location of site for substation, Main Electrical Connections, Graphical symbols for various types of apparatus and circuit elements on substation main connection diagram, Key diagram of typical substations, Equipment for substation and switchgear installations, Substation auxiliaries supply, Substation Earthing.

Suggested Readings:

[1]. Raina K.B. and Bhattacharya S.K., "Electrical Design, Estimating and Costing", New Age International, New Delhi, 2010

[2]. N. Alagappan & S. Ekambaram, "Electrical Estimating & Costing", TMH,2006

[3]. Dr.S.L.Uppal, "Electrical Wiring, Estimating and Costing", 5th Edition, Khanna Publishers,2003.

[4]. M.V. Deshpande, "Elements of Electrical Power Station Design", PHI 2009.

[5]. J. B. Gupta, "A Course in Electrical Installation Estimating and Costing", S. K. Kataria and Sons, India,2013.

[6]. ISI, National Electric Code, Bureau of Indian Standard Publications, New Delhi, 2011.

EE612 **Electrical Engineering Materials**

L	T	Credit
3	1	3

Course Outcomes:

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

CO's	CO Description
CO1	**Understand** various types of dielectric materials, their properties in various conditions.
CO2	**Evaluate** magnetic materials and their behavior.
CO3	**Evaluate** semiconductor materials and technologies.
CO4	**Acquire** Knowledge on Materials used in electrical engineering and applications.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	1								2
CO2	3	2	3	1								2
CO3	3	3	2	2								2
CO4	3	2	2	2								2
Avg.	**3**	**2.5**	**2.5**	**1.5**								**2**

DETAILED SYLLABUS

Module I: Dielectric Materials

Dielectric as Electric Field Medium, leakage currents, dielectric loss, dielectric strength, breakdown voltage, breakdown in solid dielectrics, flashover, liquid dielectrics, electric conductivity in solid, liquid and gaseous dielectrics, Ferromagnetic materials, properties of ferromagnetic materials in static fields, spontaneous, polarization, curie point, anti-ferromagnetic materials, piezoelectric materials, pyroelectric materials.

Module II: Magnetic Materials

Classification of magnetic materials, spontaneous magnetization in ferromagnetic materials, magnetic Anisotropy, Magnetostriction, diamagnetism, magnetically soft and hard materials, special purpose materials, feebly magnetic materials, Ferrites, cast and cermet permanent magnets, ageing of magnets. Factors effecting permeability and hysteresis.

Module III: Semiconductor Materials

Properties of semiconductors, Silicon wafers, integration techniques, Large and very large scale integration techniques (VLSI).

Module IV: Materials for Electrical Applications

Materials used for Resistors, rheostats, heaters, transmission line structures, stranded conductors, bimetals fuses, soft and hard solders, electric contact materials, electric carbon materials,

thermocouple materials. Solid, Liquid and Gaseous insulating materials, Effect of moisture on insulation.

Module V: Special Purpose Materials

Refractory Materials, Structural Materials, Radioactive Materials, Galvanization and Impregnation of materials, Processing of electronic materials, Insulating varnishes and coolants, Properties and applications of mineral oils, Testing of Transformer oil as per ISI.

Suggested Readings:

[1]. "R K Rajput", " A course in Electrical Engineering Materials", Laxmi Publications, 2009

[2]. "T K Basak", " A course in Electrical Engineering Materials", New Age Science Publications 2009

Reference Books:

[1]. TTTI Madras, "Electrical Engineering Materials", McGraw Hill Education, 2004.

[2]. "AdrianusJ.Dekker", Electrical Engineering Materials, PHI Publication, 2006.

[3]. S. P. Seth, P. V. Gupta "A course in Electrical Engineering Materials", Dhanpat Rai & Sons, 2011.

EE613 **Power System Restructuring**

L	T	Credit
3	1	3

Course Outcomes:

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

CO1	**Understand** the developments of restructuring worldwide.
CO2	**Identify** the roles and responsibilities of different entities in power market.
CO3	**Identify** issues like congestion management Ancillary Services Management.
CO4	**Evaluate** the transmission pricing schemes
CO5	**Explain** the Ancillary Services Management and the reforms in Indian power sector

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12
CO1	1	2	1	1								2
CO2	1	2	1	2		1						2
CO3	2	2	1	2		1			2			2
CO4	1	1	1	2					1			2
CO5	2	2	1	1								2
Avg.	**1.4**	**1.75**	**1.0**	**1.6**		**1**			**1.5**			**2**

DETAILED SYLLABUS

Module I: Introduction to Restructuring of Power Industry (8 Lectures)

Introduction: Deregulation of power industry, Restructuring process, Issues involved in deregulation, Deregulation of various power systems – Fundamentals of Economics: Consumer behavior, Supplier behavior, Market equilibrium, Short and long run costs, Various costs of production – Market models: Market models based on Contractual arrangements, Comparison of various market models.

Module II: Electricity Market Model (8 Lectures)

Separation of ownership and operation, Deregulated models, pool model, pool and bilateral trades model, multilateral trade model. Competitive electricity market: Independent System Operator activities in pool market, Wholesale electricity market characteristics, central auction, single auction power pool, double auction power pool, market clearing and pricing, Market Power and its Mitigation Techniques, Bilateral trading.

Module III: Transmission Congestion Management (8 Lectures)

Introduction: Definition of Congestion, reasons for transfer capability limitation, Importance of congestion management, Features of congestion management – Classification of congestion management methods – Calculation of ATC - Non – market methods – Market methods – Nodal pricing – Inter zonal and Intra zonal congestion management – Price area congestion Management.

Module IV: Locational Marginal Prices and Financial Transmission Rights (5 Lectures)

Mathematical preliminaries: - Locational marginal pricing– Lossless DCOPF model for LMP calculation – Loss compensated DCOPF model for LMP calculation – ACOPF model for LMP calculation – Financial Transmission rights.

Module – V: Transmission Pricing Schemes (7 Lectures)

Introduction to transmission pricing, Principles of transmission pricing, Classification of transmission pricing, Rolled-in transmission pricing paradigm, Marginal transmission pricing paradigm, Composite pricing paradigm, Merits and de-merits of different paradigms, Classification of loss allocation methods, Pro-rata methods, Incremental methods, Power flow tracing based allocation.

Module – VI: Ancillary Service Management (4 Lectures)

Introduction of ancillary services – Types of Ancillary services – Classification of Ancillary services – Load generation balancing related services – Voltage control and reactive power support devices – Black start capability service.

Module-VII: Reforms in Indian Power Sector (2 Lectures)

Introduction – Framework of Indian power sector – Reform initiatives - Availability based tariff – Electricity act 2003 – Open access issues – Power exchange – Reforms in the near future.

Suggested Readings:

[1]. Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker, "Restructured electrical power systems: operation, trading and volatility" Pub., 2001.

[2]. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen, "Operation of restructured power systems", Kluwer Academic Pub., 2001.

[3]. Leo Lei Lai, "Power System Restructuring and Deregulation: Trading, Performance and Information Technology" Wiley Pub. November 2001.

[4]. Steven Stoft, "Power system economics: designing markets for electricity", John Wiley & Sons, 2002.

Reference Books:

[1]. Making competition work in electricity Sally Hunt, John Wiley & Sons, Inc., 2002.

[2]. Marija llic, Francisco Galiana and Lestor Fink , Power System Restructuring Engineering & Economics , Kulwer Academic Publisher, USA-2000.

EE614 **Green Energy Technology**

L	T	Credit
3	1	3

Course Outcome:

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

CO1	**Identify** different non-conventional energy system and **realize** their importance in today's scenario.
CO2	**Analyze** the performance and limitations of the solar and wind energy conversion system.
CO3	**Understand** the concept behind the bio-mass, geothermal, tidal, ocean thermal and wave energy conversions.
CO4	**Outline** the basics of fuel cells and hydrogen production and storage.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1		1	1		1					1
CO2	3	2	2	2	1		1					1
CO3	2	1	1	1	1		1					1
CO4	2	1	1	1	1		1					1
Avg.	**2.5**	**1.25**	**1.33**	**1.25**	**1**		**1**					**1**

DETAILED SYLLABUS

Module I: Introduction **(4 Lectures)**

Basics of energy, conventional energy sources, fossil fuels limitations, renewable energy sources, advantages and limitations, global energy scenario, energy scenario of India, new technologies (hydrogen energy, fuel cells, bio fuels).

Module II: Solar Energy **(12 Lectures)**

Theory of solar cells, solar cell materials, I-V characteristics of solar cell, PV module, PV array, MPPT, PV systems, Stand alone and grid connected PV systems, storage, PV based water pumping, solar radiation and its measurement, flat plate collectors and their materials, applications and performance, solar thermal power plants, limitations.

Module III: Wind Energy **(10 Lectures)**

Wind power and its sources, site selection, power in the wind, impact of tower height, classification of wind turbine and rotors, wind energy extraction, betz'z limit, wind characteristics, performance and limitations of wind energy conversion systems.

Module IV: Biomass and Geothermal energy **(5 Lectures)**

Availability of biomass and its conversion theory, types of biomass, gasification, biogas plant, biomass cogeneration, resources of geothermal energy, thermodynamics of geo-thermal energy conversion, geothermal power generation, environmental considerations.

Module V: Tidal, Wave and Ocean energy (6 Lectures)

Introduction to tidal energy, tidal characteristics, tidal power plant, tidal power development in India, introduction to wave energy, factors affecting wave energy, principles of wave energy plant, OTEC, applications of OTEC.

Module VI: Emerging technologies for power generation (5 Lectures)

Fuel cells, Principle of working of various types of fuel cells and their working, performance and limitations, future potential of fuel cells, emergence of hydrogen, cost analysis of hydrogen production, hydrogen storage.

Suggested Readings:

[1] Non-Conventional Energy Resources, D.S. Chauhan, New Age International Pvt Ltd., 2006.

[2] D. P. Kothari, Rakesh Ranjan, Renewable Energy Sources and Emerging Technologies, PHI, India,2011.

[3] Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997

[4] S. P. Sukhatme, Solar Energy, TMH, India. 2008.

[5] Introduction to Wind Energy Systems: Basics, Technology and Operation (Green Energy and Technology), by Hermann-josef Wagner, ISBN: 9783642020223, Publisher: Springer, September 2009.

[6] Biofuels - Securing the Planet's Future Energy Needs, Edited by A Demirbas Springer 2009

[7] Fuel Cells: The Sourcebook - New Edition 2004 Escovale 2004.

Reference Books:

[1] John Twiden and Tony Weir, Renewable Energy Resources, BSP Publications, 2006.

[2] Renewable Energy, Third Edition, Bent Sorensen, Academic Press August 2004

[3] Wind Energy Explained: Theory, Design and Application, by J. F. Manwell, ISBN: 9780470015001, Publisher: John Wiley & Sons, Publication Date: February 2010 .

[4] L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.

Open Elective-II
(Any One)

EE621

Advanced Control Systems*

L	T	Credit
3	1	3

Course Outcomes:

After successful completion of the course, students should be able to:

CO's	CO Description
CO1	**Evaluate** the output of a digital system for a given input.
CO2	**Describe** the dynamics of a Linear, Time Invariant systems through difference equations.
CO3	**Analyze** digital systems using the Z-transformation, state space methods.
CO4	**Design** digital controllers for physical systems.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2		1	1	1	1					1
CO2	3	1	3	2	2							
CO3	3	2		2	2							
CO4	3	3	3	3	3		1					2
Avg.	**3**	**2**	**3**	**2**	**2**	**1**	**1**					**1.5**

DETAILED SYLLABUS

Module I: Sampling and Reconstruction (8 Lectures)

Introduction to digital control system, Examples of Data control systems, Sampler, Sampling Theorem, Data Reconstruction: Digital to Analog conversion and Analog to Digital conversion, sample and hold operations.

Module II: Modeling discrete-time systems by pulse transfer function (8 Lectures)

Revisiting Z-transform: Introduction to Z – transforms, Theorems of Z – Transforms, inverse Z-transforms, Z-Transform method for solving difference equations. Mapping of S-plane to Z-plane, Pulse transfer function, Pulse transfer function of closed loop system, sampled signal flow graph

Module III: State Space Analysis (12 Lectures)

State variables, State model for linear continuous-time system. Types of state models, Eigen value and Eigen vectors, Solution of state equation, State transition matrix and its Properties.

Discrete state space model: Introduction to state variable model, various canonical forms, Characteristic equation, state transition matrix, Solution to discrete state equation.

Module IV: Controllability, Observability & Stability (8 Lectures)

Concepts of Controllability and Observability, Tests for controllability and Observability Duality between Controllability and Observability. Stability analysis of discrete time systems: Jury stability

test Stability analysis using Bi-linear transformation.

Module V: State Feedback Controller **(6 Lectures)**

Design of state feedback controller through pole placement – Necessary and sufficient conditions. Observer: Full Order Observer, Reduced Order Observer. Lyapunov Stability Theorem.

Suggested Readings:

[1]. Discrete-Time Control systems – K. Ogata, Pearson Education/PHI, 2nd Edition

[2]. B. C Kuo, Digital Control Systems, 2nd Edition, Oxford University Press, Inc., 1992.

Reference Books:

[1]. F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems, Addison-Wesley Longman, Inc., Menlo Park, CA , 1998.

[2]. Digital Control and State Variable Methods by M.Gopal, TMH.

EE622 **Soft Computing Techniques**

L	T	Credit
3	1	3

Course Outcomes:

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

CO1	**Distinguish** the concept between the hard and soft computing techniques.
CO2	**Understand** the basic concept of the Artificial Neural Network (ANN).
CO3	**Understand** the basic concept of the fuzzy logic system
CO4	**Explain** the concept of Genetic Algorithm (GA) and its limitation.
CO5	**Choose** the different kind of evolutionary programming for multi objective optimization problem based on their application.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	1	2							2
CO2	3	3	3	2	2							2
CO3	3	3	3	2	2							2
CO4	3	3	3	3	2							2
CO5	3	3	3	2	2							2
Avg.	**3**	**3**	**3**	**2**	**2**							**2**

DETAILED SYLLABUS

Module I: Fundamentals of Soft Computing Techniques (4 Lectures)

Conventional and Modern Control System, Intelligence, Soft and Hard Computing, Artificial Intelligence.

Module-II: Artificial Neural Network (10 Lectures)

Introduction to Artificial neural networks-biological neurons, Basic models of artificial neural networks- Connections, Learning, Activation Functions, McCulloch and Pitts Neuron.

Learning rule- Hebbian Learning, Perceptron Learning, Delta Learning- Training and Testing algorithm, Adaptive Linear Neuron, Back Propagation Network – Architecture, Training algorithm.

Module-III: Fuzzy Logic System-I (8 Lectures)

Fuzzy Logic- Fuzzy sets- Properties- Operation on fuzzy sets, fuzzy relations- operations on fuzzy relations.

Fuzzy membership functions, fuzzification, Methods of membership value assignments- intuition- inference- rank ordering, Lambda- cuts for fuzzy sets, Defuzzification methods.

Module –IV: Fuzzy Logic System-II (7 Lectures)

Truth values and Tables in Fuzzy Logic, Fuzzy propositions, Formation of fuzzy rules – Decomposition of rules- Aggregation of rules, Fuzzy Inference Systems- Mamdani and Sugeno types, Neuro-fuzzy hybrid systems – characteristics- classification

Module-V: (8 Lectures)

Introduction to genetic algorithm, operators in genetic algorithm – coding – selection – cross over – mutation, Stopping condition for genetic algorithm flow, Generational Cycle, Applications.

Module-VI: (5 Lectures)

Evolutionary Programming, Multi-objective Optimization Problem Solving and its applications, Genetic- neuro hybrid systems, Genetic-Fuzzy rule based system.

Suggested Readings:

[1]. N.P Padhy, Artificial Intelligence and Intelligent Systems- Oxford University Press.

[2]. S. N. Sivanandam and S. N. Deepa, Principles of Soft Computing- Wiley India.

[3]. Timothy J. Ross, Fuzzy Logic with engineering applications – Wiley India.

[4]. M.E. E1- Hawary , Artificial Intelligence application in Power Systems, IEEE Press,2009

[5]. Jan Jantzen, Foundations of Fuzzy Control, A practical approach, Wiley,2013

[6]. M Gopal, Digital Control and State Variable Methods, conventional and neural-fuzzy control system, Published by Tata McGraw Hill Education Private Ltd,2012

[7]. David E Goldberg, Genetic Algorithms, published by Pearson 2008

Reference Books:

[1]. Satish Kumar, Neural Networks- Prentice Hall of India.

[2]. N. K. Sinha and M.M. Gupta, Soft Computing and Intelligent Systems: Theory & Applications- Academic Press/ Elsevier, 2009.

[3]. Simon Haykin, Neural Network- A comprehensive Foundation- PHI, Inc.

[4]. Eberhart and Y. Shi, Computational Intelligence: Concepts to Implementation, Morgan Kaufman/ Elsevier, 2007.

EE623 **Power Electronics*** **L T Credit**

3 1 3

Course Outcomes:

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

CO's	CO Description
CO1	To **understand** different power semiconductor devices and their characteristics.
CO2	To **understand** the operation, characteristics and performance parameters of AC to DC Converters.
CO3	To **study** the operation and basic topologies of DC-DC Converters
CO4	To learn the different modulation techniques of PWM inverters and to **understand** commutation techniques.
CO5	To **study** the operation of AC voltage controller and it's various configurations.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2	1		1					1
CO2	2	2	3	3	2		1					1
CO3	2	2	3	2	1	1	1					1
CO4	2	3	2	2	2	1	1					1
CO5	2	3	3	2	1	1	1					1
Avg.	**2.2**	**2.4**	**2.6**	**2.2**	**1.4**	**1**	**1**					**1**

DETAILED SYLLABUS

Module I: Power Semiconductor Devices (10 Lectures)

Power Diode, BJT, MOSFET, IGBT, Thyristor, GTO: constructional features, I-V Characteristics, switching Characteristics, Firing circuit for thyristor; protection of thyristor and gate drive circuit, Turn on techniques, Voltage and current commutation of a thyristor.

Module II: AC-DC Converters (8 Lectures)

Introduction, Single-phase half-wave and full-wave rectifiers with R, R-L and R-L-E load; effect of source inductance, Three-phase full-bridge rectifier with R, R-L and R-L-E load; freewheeling effect, power factor improvement.

Module III: DC-DC Buck and Boost Converter (6 Lectures)

Introduction, Elementary chopper with an active switch and diode, concepts of duty ratio and average voltage, quadrant operation of chopper. power circuit of a buck, boost and buck-boost converter, analysis and waveforms at steady state, duty ratio control of output voltage.

Module IV: Single-Phase Voltage Source Inverter (6 Lectures)

Introduction, Single-phase voltage source inverter, operation and analysis, concept of average voltage over a switching cycle, sinusoidal pulse width modulation, modulation index and output voltage. Current source inverter.

Module V: Three-Phase Voltage Source Inverter (6 Lectures)

Three-phase voltage source inverter, operation and analysis, 120- degree conduction, 180-degree conduction, three-phase sinusoidal pulse width modulation.

Module VI: AC Voltage Controllers (6 Lectures)

Introduction, principle of on-off control, principle of phase control and integral cycle control, configuration of three phase controllers, cycloconverter.

Suggested Readings:

[1]. M. H. Rashid, "Power electronics: circuits, devices, and applications", Pearson Education India, 2009.

[2]. N. Mohan and T. M. Undeland, "Power Electronics: Converters, Applications and Design", John Wiley & Sons, 2007.

[3]. R. W. Erickson and D. Maksimovic, "Fundamentals of Power Electronics", Springer Science &Business Media, 2007.

[4]. L. Umanand, "Power Electronics: Essentials and Applications", Wiley India, 2009.

EE624 **Mine Electrical Engineering*** **L T Credit**

3 1 3

Pre-requisite: Basic Electrical Engineering and Basic Electronics Engineering.

Course Outcomes:

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

CO's	CO Description
CO1	**Understand** different types of power supply systems and protection schemes used underground coal mines.
CO2	**Understand** different types of circuit breakers and relay used in Mines.
CO3	**Analyze** illumination, Intrinsically Safe circuit methods of attaining intrinsic safety, Zener safety barriers and their applications in mines.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

1. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1		1						2
CO2	3	3	2	1		1						2
CO3	3	3	2	1		1						2
CO4	3	3	2	1		1						2
CO5	3	3	12	1		1						2
Avg.	**3**	**3**	**2**	**1**		**1**						**2**

DETAILED SYLLABUS

Module I:

Types of electrical power supply systems for underground coal mines – solidly earthed, restricted neutral and insulated – neutral systems of electrical power supply; their comparisons.

Module II:

Earth fault protection techniques for above mine power supply systems, sensitive and fail-safe earth fault relays. On-line insulation monitoring for insulated-neutral electrical distribution system.

Module III:

Mining type circuit breakers – Air circuit breaker, vacuum and Hexa Sulfa Flouride (Sf6) circuit breakers, Field switch, Tran switch Unit, Gate End Box, Drill Panel.

Module IV:

Electrical power planning for mechanized longwall faces – general scheme of electrical power distribution, voltage drop problems and remedial measurers; Inbye substation capacity selection. General scheme of electrical power distribution in opencast projects, Quarry substation capacity selection. Choice of restricted-neutral and insulated-neutral systems in open cast mines.

Module V:

Illumination planning for mines – underground roadway lighting system; intrinsically-safe lighting system for longwall faces, opencast mine lighting. Unit-VI Earthing practice in mines – earth pits, earthing of mobile electrical equipment in mines. Mining cables – types, constructional details; layout of cables through shaft and other locations.

Module VI:

Principles of flame proof enclosures. Intrinsically safe circuit methods of attaining intrinsic safety, zeener safety barriers and their applications. Indian electricity rules as applied to mines.

Suggested Readings:

[1] A Text Book on Power Systems Engineering – Soni Gupta, Bhatnagar, Chakarbarti, Dhanpat Rai & Sons.

[2] Electrical Equipment in mines- H. Cotton.

[3] Switchgear and Protection- S.S. Rao Khanna Publications.

[4] Indian Electricity Rules.

[5] Principles of Mine Planning J. Bhattacharya, Allied Publications.

Reference Books:

[1] Universal Mining School Series (UK)

[2] Coal Mining Practice- J.C. F Statharm Vol III, Heart Series.

[3] Electrical Power Systems – C.L. Wadhwa, New Age International Publishers

EE625

Green Energy Technology*

L	T	Credit
3	1	3

Course Outcome:

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

CO1	**Identify** different non-conventional energy system and **realize** their importance in today's scenario.
CO2	**Analyze** the performance and limitations of the solar and wind energy conversion system.
CO3	**Understand** the concept behind the bio-mass, geothermal, tidal, ocean thermal and wave energy conversions.
CO4	**Outline** the basics of fuel cells and hydrogen production and storage.

CO's-PO's Mapping Matrix:

Enter correlation levels1, 2 or 3 as defined below-

2. Slight (low) 2. Moderate (Medium) 3. Substantial (High)

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1		1	1		1					1
CO2	3	2	2	2	1		1					1
CO3	2	1	1	1	1		1					1
CO4	2	1	1	1	1		1					1
Avg.	**2.5**	**1.25**	**1.33**	**1.25**	**1**		**1**					**1**

DETAILED SYLLABUS

Module I: Introduction **(4 Lectures)**

Basics of energy, conventional energy sources, fossil fuels limitations, renewable energy sources, advantages and limitations, global energy scenario, energy scenario of India, new technologies (hydrogen energy, fuel cells, bio fuels).

Module II: Solar Energy **(12 Lectures)**

Theory of solar cells, solar cell materials, I-V characteristics of solar cell, PV module, PV array, MPPT, PV systems, Stand alone and grid connected PV systems, storage, PV based water pumping, solar radiation and its measurement, flat plate collectors and their materials, applications and performance, solar thermal power plants, limitations.

Module III: Wind Energy **(10 Lectures)**

Wind power and its sources, site selection, power in the wind, impact of tower height, classification of wind turbine and rotors, wind energy extraction, betz'z limit, wind characteristics, performance and limitations of wind energy conversion systems.

Module IV: Biomass and Geothermal energy **(5 Lectures)**

Availability of biomass and its conversion theory, types of biomass, gasification, biogas plant, biomass cogeneration, resources of geothermal energy, thermodynamics of geo-thermal energy conversion, geothermal power generation, environmental considerations.

Module V: Tidal, Wave and Ocean energy (6 Lectures)

Introduction to tidal energy, tidal characteristics, tidal power plant, tidal power development in India, introduction to wave energy, factors affecting wave energy, principles of wave energy plant, OTEC, applications of OTEC.

Module VI: Emerging technologies for power generation (5 Lectures)

Fuel cells, Principle of working of various types of fuel cells and their working, performance and limitations, future potential of fuel cells, emergence of hydrogen, cost analysis of hydrogen production, hydrogen storage.

Suggested Readings:

[1] Non-Conventional Energy Resources, D.S. Chauhan, New Age International Pvt Ltd., 2006.

[2] D. P. Kothari, Rakesh Ranjan, Renewable Energy Sources and Emerging Technologies, PHI, India,2011.

[3] Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997

[4] S. P. Sukhatme, Solar Energy, TMH, India. 2008.

[5] Introduction to Wind Energy Systems: Basics, Technology and Operation (Green Energy and Technology), by Hermann-josef Wagner, ISBN: 9783642020223, Publisher: Springer, September 2009.

[6] Biofuels - Securing the Planet's Future Energy Needs, Edited by A Demirbas Springer 2009

[7] Fuel Cells: The Sourcebook - New Edition 2004 Escovale 2004.

Reference Books:

[1] John Twiden and Tony Weir, Renewable Energy Resources, BSP Publications, 2006.

[2] Renewable Energy, Third Edition, Bent Sorensen, Academic Press August 2004

[3] Wind Energy Explained: Theory, Design and Application, by J. F. Manwell, ISBN: 9780470015001, Publisher: John Wiley & Sons, Publication Date: February 2010 .

[4] L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.

Laboratory/ Sessional

EE601P		P	Credit
	Power Systems-II Laboratory		
		3	**1**

This Laboratory Experiments may be performed in physical/ virtual platform (as per availability of list of experiments in virtual lab portal).

List of the Experiments

Any 10 experiments out of which atleast 7 experiments from Group-A and 3 experiments from Group-B.

Group-A: SIMULATION BASED (USING MATLAB OR ANY OTHER SOFTWARE)

1) Formation of Bus admittance matrix
2) Solution of load flow problem using Gauss-Seidel method
3) Solution of load flow problem using Newton-Raphson method.
4) Solution of load flow problem using Fast Decoupled Method
5) Formation of Z-bus matrix
6) Application of Swing equation and its solution to determine transient stability
7) Simulation of LFC for two area power system
8) Economic load dispatch without considering network losses
9) Economic load dispatch considering network losses
10) To perform symmetrical fault analysis in a power system

Group B: HARDWARE BASED

1) To determine negative and zero sequence synchronous reactance of an alternator.
2) To determine fault current for L-G, L-L, L-L-G and L-L-L faults at the terminals of an alternator at very low excitation.
3) To determine location of fault in a cable using cable fault locator
4) Determination of power angle characteristics of an Alternator

NOTE : At least ten experiments are to be performed, minimum seven experiments should be performed from above list. Remaining three experiments may either be performed from the above list or designed & set by the concerned institution as per the scope of the syllabus.

EE602P		P	Credit
	Power Electronics Laboratory		
		3	**1**

This Laboratory Experiments may be performed in physical/ virtual platform (as per availability of list of experiments in virtual lab portal).

List of the Experiments

Atleast 10 experiments should be performed in this Laboratory.

1) To study 1-phase half wave and full wave mid-point uncontrolled rectifier
2) To study 1-phase half wave and full wave bridge controlled rectifier.
3) Study of three-phase half & fully wave controlled bridge converter with R and RL load.
4) To study V-I characteristics of SCR.
5) Study of AC voltage controller using TRIAC with R and RL load.
6) To study different triggering circuits for thyristors.
7) To study the operation of buck converter.
8) To study the operation of boost converter.
9) To study the function of Inverter trainer
10) To study class A and Class B commutation circuit.
11) To study class C and class D commutation circuit
12) To study the single phase cycloconverter with R and R-L Loads.
13) To study the operation of single phase dual converter fed PMDC motor
14) To determine speed vs load characteristics of BLDC motor.
15) To perform speed control of 3-phase induction motor using v/f control method

NOTE: At least ten experiments are to be performed, minimum seven experiments should be performed from above list. Remaining three experiments may either be performed from the above list or designed & set by the concerned institution as per the scope of the syllabus.

EE603P	Simulation Laboratory	P	Credit
		3	1

This Laboratory Experiments may be performed in physical/ virtual platform (as per availability of list of experiments in virtual lab portal).

List of the Experiments

Atleast 10 experiments should be performed in this Laboratory.

These experiments can be performed using any software / FOSS (Free and Open Source Software) available at the institute.

1) Simulation of Single Phase Half Wave Uncontrolled Rectifier with R and RL-Load.
2) Simulation of Single Phase Half Wave Controlled Rectifier with R and RL-Load.
3) Simulation of Single Phase Semi Controlled Rectifier with R and RL-Load.
4) Simulation of Single Phase Full Wave Uncontrolled Rectifier with R and RL- Load.
5) Simulation THD Analysis of Single Phase Full Wave Controlled Rectifier with R and RL-Load.
6) Simulation and THD Analysis of Single Phase Full Wave Rectifier with RLE-Load.
7) Simulation and THD Analysis of Three Phase Half Wave Rectifier using R and RL-Load.
8) Simulation and THD Analysis of Three Phase Full Bridge Converter using R and RL-Load.

NOTE: At least ten experiments are to be performed, minimum seven experiments should be performed from above list. Remaining three experiments may either be performed from the above list or designed & set by the concerned institution as per the scope of the syllabus.

EE604P		P	Credit
	Electrical Workshop		
		3	**1**

This Laboratory Experiments may be performed in physical/ virtual platform (as per availability of list of experiments in virtual lab portal).

List of the Experiments

Atleast 10 experiments should be performed in this Laboratory.

1) To study the different types of cable and conductors.
2) To perform house wiring for bulb, fan and a 3-pin socket.
3) To study the different types of motor starters.
4) To perform and verify the connection of fluorescent lamp, circuit, lines.
5) To Study Institute Substation.
6) Determination of dielectric strength of the given transformer oil.
7) To study different components of CT & PT.
8) To measure the resistance by using earth resistance tester.
9) To study of lap, wave, short pitch winding in machine.
10) To measure insulation resistance of 3 - induction motor.

NOTE: At least ten experiments are to be performed, minimum seven experiments should be performed from above list. Remaining three experiments may either be performed from the above list or designed & set by the concerned institution as per the scope of the syllabus.