Compulsory Subjects

IC 402 Engineering Management

EL 403 Power Systems

EL 404 Circuit and Field Theory

EL 405 Electrical Machines

EL 406 Measurements and Control

EL 407 Design of Electrical Systems

Optional Subjects

(Any three from any one Group)

Group I Power Systems

EL 411 Energy Systems

EL 412 Power Electronics

EL 413 High Voltage Engineering and Power Apparatus

EL 414 Power System Performance

EL 415 Micro-processors and Micro-controllers

Group II Electrical Machines and Drives

EL 421 Advanced Aspects of Electrical Machines

EL 422 Power Electronics

EL 423 Electrical Drives

EL 424 Electrical Power Utilization

EL 425 Micro-processors and Micro-controllers

Group III Control and Instrumentation

EL 431 Control Theory

EL 432 Power Electronics

EL 433 Process Control Systems

EL 434 Instrumentation Systems

EL 435 Micro-processors and Micro-controllers

Engineering Management

Group A

Management and Organisations

Management process: Definition, planning organizing, directing, controlling, coordinating, types of management.

Organisation Definition, planning, design and development, types of organizations.

Management planning and control: Classical, new classical and modern principles. General Management, scientific management, engineering, management, systems management.

Planning: Procedures, resources and constraints, objectives, goals, policies and procedures.

Control: Setting of reference or standards, appraisal or evaluation, monitoring and controlling, types of control.

Human resource planning and management, selection, recruitment, training, retraining, skill development, competence development, promotion and career development, participative management, trade unions, and collective bargaining,

Management of Physical Resources

Plant: site selection procedures, factors affecting selection. Layout-types and relative merits and demerits, Maintenance-Objectives, different types of associated decisions, strategies for effective maintenance, computer applications.

Material : Functions, objectives, planning and control including inventory models with or without storage costs, price break (excluding dynamic and probabilistic considerations). Different classes of inventory. Material Requirement Planning (MRP).

Group B

Financial management: Introduction to standard forms of financial statements, i.e., balance-sheet, profit and loss, and income statement. Fixed and current asset items. Fixed and current liability items. Linkage of two successive balance-sheets through income or profit and loss statement. Funds flow statement. Financial ratios and their implications.

Managerial economics: Concepts, theory of production, marginal productivity and cost. Introduction to theory of firm.

Quality management: Quality definition, quality planning, quality control and quality management, Total quality management, ISO 9000 systems, simple quality control techniques like control charts and acceptance sampling.

Marketing management consumer behaviour, market research, product design and development pricing and promotion.

Project management: Introduction. Concept of a project, project management concepts, project simulation, cost or project and means of financing, economic evaluation criteria of the project, project implementation, project planning, scheduling and monitoring, project control (PERT, CPM techniques including crashing). Project evaluation.

Information technology and management. Role of information, management information system and decision support system, Information technology-introduction to e-business, e-commerce and integration tools like enterprise resource planning (ERP).

Power Systems

Group A

Generation of electrical power: Conventional and non-conventional methods. Typical layout of thermal and hydro power stations-main and auxiliary equipment.

Load management: Base and peak loads. Load curves Definitions of load factor, diversity factor, demand factor. Capacity planning. Load forecasting. Capital and running costs for different types of plants. Different electricity tariffs-flat rate, two part and TOD tariff.

Generator excitation systems: Speed and excitation control of generators. Load sharing of generators in a system.

Stability of power system: Definitions of transient and steady state stability. Swing equation and its solution by step-by-step method. Equal area criterion for transient stability.

Group B

Transmission of electrical power: Overhead and underground transmission line configurations. Materials for transmission line conductors and insulators. Power station and sub-station switchyard and layouts. ACSR conductors, bundled conductors. Overhead line poles, towers and cross arms.' Single and double circuit lines.

Untransposed and transposed 3-phase transmission lines. Overhead, line sag calculation. Effect of wind pressure and ice loading on transmission lines.

Transmission line parameters: Resistance, inductance and capacitance calculations. Skin and proximity effects. Corona and radio interference of EHV lines. Voltage distribution in suspension insulators. String efficiency. Different types of cables. Capacitance of cables. Intersheath grading. -

Performance of short transmission lines: Line loss, efficiency and regulation of line. Zero regulation condition of power transmission.

Performance of medium transmission lines: Nominal T and ^ representation. Regulation and efficiency of medium lines.

Performance of long transmission lines: Equivalent T and ^ representations. Propagation constant and characteristic impedance of a long line. Ferranti effect. urge impedance loading. Infinite line. Wavelength of line. Determination of A, B, C, D constants of transmission lines.

Transmission line charts: Power factor and power angle of a transmission line. Power angle diagram of an interconnector. Use of shunt and series capacitor in a transmission line.

Circuit & Field Theory

Group A

Circuit Theory

Graph of a network. Concept of tree, loop current and node pair voltage. Tie set and tie set matrices-cut set and cut set matrices. Solution of equilibrium equations on loop and node basis. Application of Laplace transforms for solving transient equations of electrical circuits. initial and final value theorems. Unit step, impulse and ramp inputs. Laplace transform for shifted and singular functions. The. convolution integral. Fourier series and its applications. Exponential form of the Fourier series. Relation between frequency spectra and. Laplace transform of the Fourier series. The concept of complex frequency, transform impedance and admittance; series and parallel. combinations.

Network theorems: Thevenin, Norton, Reciprocity, Superposition and Telegen. Terminals and ports. Driving point and transfer impedances. S-plane representation: Poles and zeros. Time domain behaviour from pole and zero plots. Procedure for finding network functions for general two-port network. Radian frequency and sinusoidal network functions in terms of poles and zeros. Resonance, Q-factor and bandwidth. Asymptotic change of magnitude with frequency in terms of poles and zeros. The symmetrical lattice..

Group B

Field Theory

Vectors and vector calculus. Gradient, divergence and curl of a vector. Gauss, Stokes and Helmholtz theorems.

Electrostatics: Potential and electric field intensity. Conducting boundaries, Coaxial spheres and cylinders. Laplace's and Poisson's equations. Electrostatic energy. Uniqueness theorem. Method of images; dipoles. Dielectric polarisation, electric flux density, permittivity. Boundary conditions. Stationary currents. Ohm's law; E.M.F. conservation of charge. Resistance of arbitrary shaped conductors. Boundary conditions and refraction, current flow lines. Numerical solutions of Laplace's equation by the method of iterations.

Magneto static : Magnetic field intensity and flux density. Vector potential. Magnetic dipole. Divergence of B. Ampere's law of force. Ampere's circuital law. Differential equation for vector potential. Magnetic polarisation and permeability. Boundary conditions for and H.

Time varying fields: Faraday's law. Dynamically and statically induced E.M.F's. Inductance and stored energy. Hysteresis loss, Maxwell's equations. Displacement current. Deviation of generalised wave equations from v1axwell's equations for the magnetic vector potential. specialization to Eddy current or diffusion equations and non dissipative wave equations.

Plane wave propagation and eddy current phenomenon as solutions of the above relevant equations. Reflection and refraction of plane waves at the plane boundary of electromagnetic media.

Electrical Machines

Group A

D.C. machines: Parallel operations of D.c. generators. Speed control of D.c. motors. Testing of D.c. motors.

Transformers: Construction of 3-phase transformers. Vector groupings. Connections of 3-phase transformers- Star, delta, zig-zag, Scott and Vee connections. Grounding transformers. On load tap changing arrangement of transformers. .

Synchronous machines: Regulation of synchronous generators. Salient pole synchronous machines. Direct and quadrature axis reactances. Synchronisation of 3-phase generators.

Starting of synchronous motors. V-curves for synchronous motors. Synchronous condensers. Load and torque angles of synchronous machines.

Group B

Three-phase induction motors: Torque-slip characteristics. Starting maximum and pull out torques. Circle diagram of induction motors. Starters for induction motor. Speed control of induction motor. Testing of induction motor.

Single-phase A.C. motors: Working principle and performance of split phase shaded pole and capacitor , motors. Series motor, repulsion motor.

Servo motors: D.C. and A.C.

Measurement and Control

Group A

Measurements

Units and standards. Measurement of electric quantities such as voltage, current and power and power factor at various frequencies.

High and low value resistance measurement. A.C. potentiometer. A.C. bridges: Owen, Anderson al Schering. Magnetic measurements: Flux, permeability a. B H loop.

High voltage measurements: D.C, A.c. and impulse. Frequency and time interval measurement.

Group B

Control

Open loop and closed loop control systems. Concept of linear and nonlinear systems. Transfer functions a block diagrams. Signal flow graph.

State variables: State equations. Matrix representation of state equations. Relationship between state equations and transfer functions.

Time response: Transient analysis of feedback systems - First and second order systems. Steady state error and error coefficients.

Frequency response: Polar plots, Bode plots, logarithmic vs. phase plots.

Stability: Concept and determination of absolute stability. Routh's criterion. Nyquist criterion. Rela1 stability. Determination of gain and phase margin from Nyquist and Bode plots.

Root locus: Definitions. Construction of root loci. Root contours, S plane analysis of systems.

Control system components: D.C. and A.C. tachogenerator, synchros, D.C. and A.C. preamplifier Servo potentiometers and gyroscopes.

Design of Electrical Systems

Group A

Design of load boxes and rheostats.

DC machine design: Main dimensions, output equation, choice of number of poles, choice of type of winding, design of commutator and brush gear, design of field poles and field windings.

Armature windings: Basic principles and classification of armature windings, single layer and double layer windings, simple and multiple windings. Different types of AC windings, commutator windings, AC winding factors. Armature reaction in AC machines, causes and elimination of harmonies. Skin effect and eddy current losses in armature conductors. Design of different types of motor starters, field regulators.

Group B

Transformer design: Single-phase and three-phase- main dimensions, core and winding design, magnetizing current, losses, reactance of windings, tank design.

Induction motor design: Three-phase-main dimensions. Stator and rotor windings. Calculation of no load and pull out currents. Torque and speed calculations.

Distribution design: Fixing location of distribution transformer. Plotting of load curves and determination of maximum demand. Design of distributors and feeders. Design of domestic wiring.

Energy Systems

Group A

Sources of conventional energy. Fossil fuels—solid fossil fuel—coal and lignite, formation, physical properties and chemical properties. Combustion equations. Coal analyses—proximate and ultimate, determination of air/fuel ratio for coal-fired boilers.

Liquid and gaseous fossil fuels: Petroleum and natural gas. Physical and chemical properties. Combustion equations. Manufactured and by-product gases composition, heating value, use. Air/fuel ratio for liquid and gaseous fuel boilers.

Cogeneration and combined cycle generation. Fiuidised bed combustion. Nuclear fission reactions: Fuel isotope energy release in fission. Fertile isotopes.

Converter and breeder reactors. Nuclear fusion-fusion reactions. Energy release in fusion. Advantages and disadvantages of nuclear fusion.

Hydro energy; Run of the river and pumped storage systems. Energy and power equations. Available water head. Impulse and reaction type hydro turbines.

Environmental effects of conventional energy conversion. Energy conservation and energy audit.

Group B

Different forms of non-conventional energy sources: Solar, wind, geothermal, ocean, biogas, etc.

Two types of non-conventional energy conversion processes: a) Direct conversion to electrical energy, viz, photovoltaic, fuel cells, etc.; b) Primary conversion to non-electrical energy viz. solar-thermal, wind-turbine, ocean-thermal, tidal, etc.

Solar: Terrestrial solar radiation, solar-thermal conversion, techniques of collection, storage and utilization, types of solar collectors, selective surfaces, thermal processes, power generation, etc.

Photoelectric effect, solar cells, crystalline and amorphous semiconductors as solar cell materials, equivalent circuit and efficiency considerations.

Wind: Principles of wind power, wind-turbine operation, state characteristics, small machines, large machines.

Geothermal and ocean: Origin and types of geothermal energy, vapour dominated systems, liquid dominated systems, flashed-steam type.

Ocean temperature differences, open cycle, closed cycle, ocean-waves, energy and power from wave, tides, simple single pool tidal system.

Biogas: Biogas conversion mechanisms, source of waste, simple digester, composition and calorific value of biogas.

Chemical: Principles of electrochemical cell operation, fuel cells, different components of fuel cells, hydrogen-oxygen fuel cells, hydro-carbon fuel cells, Faraday's law of electrolysis and thermodynamics of electrochemical energy conversion, ideal cell voltage, ideal cell efficiency, practical limitations.

Comparative study of conventional and non-conventional energy conversion as regards efficiency, economics and environmental effects.

Power Electronics

Group A

Devices

Power diodes, uncontrolled rectification and power loss during transients. Bipolar junction transistor. Power MOSFET, IGBT, GTO and LASCR, UJT, UJT oscillator, its design and frequency stability.

Driver circuit, pulse transformer and opto coupler. Thyristor, 2-transistor analogy, triggering circuits, dv/dt and di/dt protections, snubber circuit and its design.

Cooling and head sinks. Natural and forced commutations. DC choppers, step-down and step-up operations, thyristor choppers and switching mode regulators.

Group B

Applications

Bl-2, M-2, B-6 and M-6 half/full controlled circuits with R and R-L loads. Principle of phase control, circuits for control and UPS. l-O and 3-0 cycloconverter and harmonic reduction.

Inverters: Series inverter, domestic inverter, PWM inverter, auxiliary commutated thyristor inverters, complementary commutated thyristor inverters, current-source inverters, 12-pulse converters and hvdc link.

D.C. drives: one-phase semiconverter/full-converter drives, 3-phase semiconverter/full/dual-converter drives, 2/4-quadrant chopper drives.

Induction motor drives, V/f control and closed-loop control.

High Voltage Engineering and Power Apparatus

Group A

Breakdown phenomena: Breakdown of gaseous medium, mechanism of charge multiplication, secondary emission, Townsend theory, Streamer theory, Paschens law, corona, effect of polarity of voltage on corona and breakdown process.

Breakdown of solid: Intrinsic breakdown, thermal breakdown, electro-mechanical breakdown, streamer breakdown.

Breakdown of liquid: Breakdown of commercial liquid, cavitation theory, bubble theory, suspended particle theory.

Insulating materials. Properties of traditional insulating materials, SF^, vacuum, air, insulating oils, ceramics, epoxy resins, PVC, PTFF, PMMC, fibre glass, polyethylene.

Insulation resistance. Tacking index. Electrical and mechanical properties of insulators used in transmission line. Different types of line insulators. String efficiency, bushings, general design approach of bushing.

Cables: Different types of cables. Paper insulated cables, XLPE cables, gas-filled cables, technology and principles. Generation of travelling waves in transmission lines, reflection and transmission constants.

Power system grounding: Solid grounding, resistance grounding, reactance grounding, grounding through earthing transformer, resonant grounding.

Group B

Voltage surges: Lightning phenomena, lightning induced overvoltage, direct stroke, indirect stroke-Protection of power stations and sub-stations and transmission line against direct strokes.

Protection of electrical apparatus against travelling waves. Lightning arrestors—expulsion type, valve type, magnetic blow-out type and metal oxide type.

Insulation co-ordination: Determination of the line insulation, basic impulse level and insulation level of substation equipment. Selection of lightning arrester. Establishment of impulse withstand level. Overvoltage due to switching. Reduction of switching overvoltage.

Generation of high voltage and current in high voltage laboratory. Generation of high AC, DC and impulse voltage. Generation of high impulse current, impulse generator, testing transformer, source resonant circuit.

Non-destructive testing of- materials and electrical apparatus. Measurement of DC resistivity, measurement of dielectric constant and loss factors, partial discharge measurement.

Preventive testing of insulation: High voltage testing of insulators, bushings, cables and transformers. High voltage testing of surge diverters.

Power System Performance

Group A

An overview of modern power system: Layout of typical power system—generating station, substation, transformer, transmission line, distribution, load. Symbols and circuit representation of various components of the system. Single line diagram.

Per unit method of calculation: Base quantities and per unit values, modification of per unit values- due to change of base, equivalent circuit of transformer on per unit basis, choice of base quantities for power system analysis, advantages of per unit method of calculation, per unit impedance diagram of a power system.

Symmetrical components: Transformation of voltage, current and impedance to symmetrical component system, complex power in terms of transformed voltage and currents, positive, negative and zero sequence impedances of different power system components; equivalent circuits in terms of symmetrical component quantities, advantage of symmetrical component representation.

Fault studies: Symmetrical three-phase fault calculation, fault MVA and circuit breaker capacity, current limiting reactor, their placement and usefulness.

Unsymmetrical faults, classification, analysis of L-G, L-L and L-L-G fault using symmetrical components, equivalent circuit for representation of different kinds of faults, calculation of fault current and post-fault voltages. Arcing ground, its consequences and remedy.

Load flow study: The basic load flow problem and its importance, classification of system bus bars, formulation of load flow equations using bus admittance matrix, tteiative solution of load flow equations by Gauss-Seidel method, acceleration for convergence.

Economic load despatch: Generation cost, incremental cost, optimal loading of generators on a common bus bar, transmission loss formula, incremental transmission loss, generation scheduling taking care of transmission loss.

Group B

High voltage d.c. transmission: Historical review, merits and limitations of d.c. transmission, kinds of d.c. links, constitution of d.c. links, terminal equipment transformer, converter, choke and filter; gate control and operation of three-phase thyristor bridge as rectifier and inverter, relationship between input and output voltage and current in the bridge convener, active and reactive power; control of current and-voltage in a d.c. link, back-to-back connection and its usefulness.

Power system control: Automatic load frequency and voltage control, speed governor, load sharing among synchronous generators, exciter, brushless excitation system.

Power system stability: Transient power output of a synchronous machine, effect of voltage regulator and governor on enhancement of transient stability. The swing equations in multi-

machine system, numerical method of solution of swing equations and assessment of transient stability.

Power system protection: Electromagnetic relays,

construction and operating principle of attracted armature, induction disc and induction cup type relay, inverse time lag relay, plug setting and time setting arrangement.

Overvoltage, overcurrent, earth fault and neutral displacement protection. Primary and backup protection, co-ordination of overcurrent relays in radial feeder protection, directional overcurrent relay, ring main and parallel feeder protection.

Distance protection for transmission lines, three zone protection, tripping circuit, impedance setting for earth fault and phase fault types relays. Errors in distance measurement, arcing fault, power swing, directional, reactance, mho, ohm and quadrilateral characteristics.

Differential protection schemes for generator and transformer, other protections of generator and transformer.

Pilot wire relays for feeders and cables, carrier relays-blocking and inter-tripping schemes, carrier equipment, carrier phase comparison.

Microprocessor & Microcontrollers

Group A

Microprocessor architecture and microcomputer systems, memory systems, input and output devices. Number systems—binary, hexadecimal and BCD numbers, 2s complement and arithmetic operations.

8085 microprocessor architecture. Memory interfacing-address decoding techniques, memory read and write operations. Memory map. Interfacing I/O devices-Memory-mapped I/O and I/O mapped I/O. Polled and interrupt modes of data transfer. 8085 interrupts, direct memory access. Introduction to 16-bit microprocessor using 8086 as an example. Concept of debugger and MASM/TASM for PC assembly language programming.

Peripheral devices. 8255 programmable peripheral interface, 8253 programmable counter timer, serial communication with SID and SOD, 8251 programmable communication interface, 8259 programmable interrupt controller, keyboard and display devices.

8085 assembly language programming: 8085 instructions—addressing modes. Stack and subroutines. 8085 programmer's model-CPU registers. Addition, subtraction and multiplication routines. Software delay and counting routines. Logical operations. Analog and digital I/O interface routines—ADC and DAC.

Software development systems: Assemblers and cross-assemblers. Microprocessor applications. Microprocessor-based system design aids and trouble-shooting techniques.

Group B

Introduction to microcontroller: Comparison of various microcontrollers. 8051 microcontroller architecture. Bi-directional data ports, internal ROM and RAM, counters/timers. Oscillator and clock.

8051 registers. Memory organisations—program memory and data memory, internal RAM and bit addressable memory, special functions, registers, memory map.

External memory systems and I/O interface. Accessing external program memory, accessing external data memory, available I/O ports during external memory access. Alternate port functions. Serial interface. 8031 interrupts. Power down modes.

8051 assembly language programming. 8051 instruction sets, addressing modes, bit level operations. Arithmetic routines, counting and timing under interrupt control, keyboard and display interface routines, accessing lookup tables.

Software development systems. Assemblers and simulators. Microcontroller based system design and applications.

Advanced Aspects of Electrical Machines

Group A

Synchronous motor analysis taking armature resistance into account, vector diagrams, power circle and excitation circle—diagrams. Performance calculations under various operating conditions.

The equation of motion or 'swing' equation for synchronous motors and generators. Solutions of linearized swing equation, small oscillations of synchronous machines. Hunting of synchronous motors, elements of large oscillation of synchronous machines, concept of transient stability.

Starting of synchronous motors with the help of damper windings, George's phenomenon. Brushless excitation of synchronous generators and motors.

Synchronous-induction motor: Slip-ring induction motor run as synchronous motor.-Different types of motor excitation. Starting and running characteristics-combined synchronous motor and induction motor circle diagrams, performance calculation, design features.

Concept of negative sequence and zero sequence reactances of synchronous machines.

Group B

Inverter operation of induction motors, space and time harmonies and their effects on the performance of induction motors.

Induction generators; Operation from bus-bars, self-excitation equivalent circuits and performance—its utility in wind power generation.

A.C. commutator machines: General construction. Derivation of generalized expressions: (a) Transformer e.m.f. and rotational e.m.f's in phase windings; (b) Transformer and rotational e.m.f's in commutator windings, uncompensated and compensated series motor: vector diagrams, circle diagram, operational characteristics and design features.

Variable reluctance and fractional and sub-fractional h.p. motors: Different types of reluctance and stepper motors, permanent magnet motors, derivation of performance equations. Control schemes and performance.

Electrical Drives

Group A

Basic concepts. Dynamics of electric drives.

Mechanical system - different speed/torque characteristics of different frictional system, windage torque. N-T characteristics of deferent industrial systems, four quadrant operation of drive systems, dynamic conditions of a drive system, steady state and transient stability of electrical drive.

Drive motors: DC motor, three-phase induction motor and synchronous motor characteristics require power losses, temperature restrictions, heating and cooling, different modes of operation (continuous/short lime intermittent duty/periodic intermittent duty), selection of motors.

Drive motor power supply: A general survey of different power supply systems for motor drive. Phase controlled line commutated converters.

DC choppers.

Inverters.

Cyclo converters. AC voltage controllers.

Group B

Control of electric motors: DC drives - single phase and 3 phase converter drives. Chopper drives, closed loop control of DC motor.

AC drives: 3 phase induction motor control, starter voltage control/rotor voltage control, voltage and frequency control, current control, closed loop control of 3-0 induction motor.

Synchronous motor control: Voltage and frequency control, closed loop control of synchronous motors.

Electrical Power Utilization

Group A

Radiation and vision: Physics of light-wave theory, quantum theory, unified theory, photon generation, visible wavelength range, standard observer curve, different forms of energy converted to visible radiation, spectral power distribution curve.

Quantities, units, standards and measurement: Luminous energy, luminous flux, spectral radiant flux, solid angle, luminous intensity, luminance, illuminance, luminous efficacy.

Colour temperature, colour rendering index, reflectance, diffuser, etc. Lambert's cosine law, inverse square law and cosine law of illumination. Polar curve, Roussea's diagram, illuminance (flux) meter, bench photometer (intensity measurement), integrating sphere (flux measurement).

Optical system of human eye.

Sources of light: Construction and electrical circuits of different sources of light, filament lamps, halogen temps, discharge lamps - sodium and mercury high pressure discharge lamps, tube and CFL lamps.

Lighting calculations for indoor and outdoor applications: Shop lighting, factory lighting, street lighting, flood lighting.

Group B

Electric heating, welding and electroplating: Induction heating—principle of operation, scope of high frequency and low frequency heating, induction heating, power supplies at different frequencies.

Induction heating furnaces—coreless and core types.

Arc heating: AC arc heating—different arc electrodes, direct and indirect arc furnace and their power supply systems, electrode regulators, condition for maximum output, necessity of reactor in arc furnace, general arc furnace transformer construction, energy balance in arc furnace, advantages of direct arc furnaces.

DC arc furnace supply system, different bottom electrodes, twin shell DC EAF (electrode arc furnace) system, advantages of DC arc heating.

Dielectric heating: Principle of operation, choice of voltage and frequency, electrode configuration.

Resistance heating: Different resistance heating materials and their properties, causes of failures.

Direct and indirect resistance heating furnace. Design of resistance elements.

Electric welding: Resistance and arc welding and equipment for such welding.

Electrolysis: Application of electrolysis, electro deposition, electro extraction, electro refining.

Control Theory

Group A

Continuous-time systems: Performance specifications in time-domain and frequency domain. Correlation between time domain and frequency domain specifications.

Error coefficients. Design approaches. Frequency domain vs. S-plane design. Types of compensation. Controllability and observability of control systems.

Cascade compensation: Lead, lag, and lag-lead compensators. Use of Bode diagram. Root locus, and Nyquist diagram for compensator design. Feedback compensator design, use of inverse Nyquist diagram, minor loop feedback compensation. PID controllers. Linear state variable feedback. Pole placement using state variable feedback.

Nonlinear systems: Types of common non-linearities. Properties of non-linear systems. Available techniques for analysing non-linear systems. Linearising approximations. Describing function techniques. Detecting limit crycling and instability. Phase plane methods. Lyapunov's stability criterion. Popov's Method for stability analysis of non-linear systems.

Group B

Discrete-time systems: Introduction to discrete-time systems.

Z-transforms, inverse Z-transforms and bi-linear transformations.

Pulse transfer functions. Tune response of sampled data systems. Effect of sample hold and dead times.

Frequency response: Bode plots, polar plots and gain (db) vs. phase plots. Stability using Jury criterion, Routh-Hurwitz criterion, Nyquist criterion, Bode plot and root locus. Design of compensators in Z-domain and W-domain.

State space representation of discrete systems and sampled-data systems. Deriving Z-transfer function model from state model of discrete systems. Solving time-invariant state equations. State transition matrix. Controllability and observability of time-invariant discrete systems.

Process Control Systems

Group A

Process control principles, process control block

diagram, loop components—sensor and transmitter, controller, final control element. Process transfer functions - process lag and dead time, self-regulating and non-self-regulating processes.

Process instrumentation diagram: Symbols and interconnections.

Process control sensors and transmitter, thermal sensors, mechanical sensors, analog signal conditioning— instrumentation amplifier, signal isolation, and filter.

Analog signal transmission systems.

Analog process controller, P, PI, PD and PID modes of operation, controller-tuning methods, on-off controllers, anti-integral windup, anti-derivative kick and controller saturation. Velocity or incremental controller. Design of analog process controller. Pneumatic process controllers-pneumatic amplifiers and relays.

Digital process controllers—theory. Digital controller in a process control loop, analog-to-digital and digital-to-analog converters. Realization of digital controller.

Final control elements: Actuators, positioners and control valves.

Recorders: Analog, digital and data loggers.

Group B

Control loop characteristics. Controllability and stability-root locus and Bode plot techniques.

Control schemes. Ratio-control, cascade control, feed -forward control and multi-loop control-P1D control. Process loop tuning-process reaction method. Ziegler-Nichols method and frequency response methods.

Characteristics of chemical processes. Heat exchangers, distillation columns, chemical reactors, pH and blending processes, delay time and its effect. Flow control, pressure control, level control, and temperature control. Boiler control-feed water control, drum-level control, combustion control and 3-point control.

Computer control of processes. Direct digital control and supervisory control. Adaptive control systems.

Instrumentation Systems

Group A

Instrument performance characteristics and specifications: Static and dynamic, analog and digital instruments. Errors in measurements—error, correction, precision, accuracy, statistical analysis of errors, mean, median, mode, standard deviation. Confidence intervals.

Cathode Ray Oscilloscope (CRO), use of CRO in voltage measurements and waveform display.

Measurements of kVAh and kVARh in three-phase load, trivector meter, summation metering, summation current transformer.

Use of IVD in impedance comparison, low resistance comparison by using IVD.

Study of bridge balance convergence and bridge sensitivity in four-arm a.c. bridges, quad bridge for comparison of resistance with standard calculable capacitor.

Group B

A/D and D/A converters, digital voltmeters and multimeters, use of flip-flop circuits in up-down couwnters, digital displays.

Electrical transducers, linear variable differential transformers (LVDT), strain gauge, fluid flow and pressure measurements, temperature transducer, light and radiation transducer.

Introduction to instrumentation amplifier, CMRR and active filter, sample and hold circuit, data transmission in digital instrument systems and PC, IEEE-488 bus, introduction to long distance data transmission (modems).