B. Tech. in ELECTRICAL & POWER ENGINEERING

Syllabus of Paper – 1

CIRCUITS & SYSTEMS

Introduction to signals, their classification and properties, different types of systems, LTI systems and their properties, periodic waveforms and signal synthesis, properties and applications of Laplace transform of complex waveform. System modeling in terms of differential equations and transient response of R, L, C, series and parallel circuits for impulse, step, ramp, sinusoidal and exponential signals by classical method and using Laplace transform. Graph theory: concept of tree, tie set matrix, cut set matrix and application to solve electric networks. Two port networks – Introduction of two port parameters and their interconversion, interconnection of two 2-port networks, open circuit and short circuit impedances and ABCD constants, relation between image impedances and short circuit and open circuit impedances. Network functions, their properties and concept of transform impedance, Hurwitz polynomial. Positive real function and synthesis of LC, RC, RL Networks in Foster's I and II, Cauer's I& II forms, Introduction of passive filter and their classification, frequency response, characteristic impedance of low pass, high pass, Band Pass and Band reject prototype section.

POWER GENERATION ENGINEERING

Introduction: Conventional & Non-Conventional Sources of Energy and their availability in India, Different Types of Power Plants, Choice of Type of Power Generation, Power Plants in India. Hydro Power Generation: Hydrology – Hydrographs, Flow Duration Curve, Mass Curve; Principle of working, Classification, Site selection; Different components & their functions; Types of Dams; Types, Characteristics & Selection of Hydro-Turbines; Specific Speed of Hydro-Turbines; Power Output Equation; Turbine Governing; Draft Tube; Bearings; Water Hammer & Surge Tank, Cavitation, General arrangement and Operation of Hydro-electric Power Plant, Mini & Micro Hydro Power Plants, Pumped Storage Power Plants; Advantages of Hydro-electric Power Plants; Hydro Power in India & future trends. Nuclear Power Generation: Principle of Nuclear Energy, Nuclear Power Plant Components & their Functions; Nuclear Fuels, Radioactivity, Nuclear Reaction & Classification; Nuclear Reactors – Types & Classification, Main Parts; Problems in Reactor Operation; Radiation Hazards; Safety Measures; Nuclear Waste & its Disposal; Nuclear Power in India. Gas Power Generation: Operating Principle; Classification – Open Cycle, Closed Cycle, Combined Cycle; Fuels for Gas Turbine Power Plants; Different Components and their functions; Gas Turbine Characteristics, Cycle Efficiency, Operational Aspects, Advantages and Limitations. Diesel Power Generation: Working principle, Types of Diesel Engines, Different parts / systems and their functions, Performance of Diesel Engine, Plant Operation and Efficiency, Heat Balance, Advantages and Disadvantages, Applications. Thermal Power Generation: Operating Principle, Site selection, Coal to Electricity, General Layout of Thermal Power Plant, Brief description of different parts/systems and their functions, Advantages and Limitations. Co-Generation: Concept; Schemes; Brief Description; Benefits & Limitations; Applications.

ELECTRICAL MACHINES

Principles of Electromechanical Energy Conversion. DC machines: construction, armature windings, induced EMF equation, torque production, magnetization curve. Types of generators and motors, characteristics, commutation and interpoles, armature reaction, Speed control of dc motor and starting. PMDC machine: Introduction and need of brushless motors. Transformers: construction, ideal and practical transformer, equivalent circuits, voltage regulation, maximum efficiency criterion. Open circuit and short circuit tests. Phasor diagrams on no load, full load, lagging and leading power factor loads. Three phase transformer. Introduction to polyphase induction machines, production of rotating magnetic flux vector, principle of operation, importance of air gap, comparison with transformer, types of rotor. Induction motors: Development of an equivalent circuit, estimation of parameters, no load and block rotor tests. Torque slip characteristics, starting of induction motors methods, deep bar and double cage rotor, power relations, speed control of induction motors. Single phase induction motor, double field revolving theory, starting methods of single phase induction motors, universal motor and introduction to switched reluctance motor. Synchronous Machine: construction, pitch factor and distribution factor, induced emf equation, equivalent circuits and phasor diagrams, power relations, OCC and SCC characteristics for voltage regulation of alternator, salient pole and cylindrical rotor machines and phasors. Effect of excitation and V curves. Power factor correction and parallel operation of synchronous generator.

CONTROL SYSTEMS

Control Systems: Introduction to basic terms, classifications & types of Control Systems, block diagrams & signal flow graphs. Transfer function, determination of transfer function using block diagram reduction techniques and Mason's Gain formula. Control system components: Electrical/ Mechanical/Electronic/A.C./D.C. Servo Motors, Stepper Motors, Tacho Generators, Synchros, Magnetic Amplifiers, Servo Amplifiers. Time – Domain Analysis: Time domain performance specifications, transient response of first & second order systems, steady state errors and static error constants in unity feedback control systems, response with P, PI and PID controllers, limitations of time domain analysis. Frequency Domain Analysis: Polar and inverse polar plots, frequency domain specifications and performance of LTI systems, Logarithmic plots (Bode plots), gain and phase margins, relative stability. Correlation with time domain performance closes loop frequency responses from open loop response. Limitations of frequency domain analysis, minimum/non-minimum phase systems. Stability & Compensation Techniques: Concepts, absolute, asymptotic, conditional and marginal stability, Routh–Hurwitz and Nyquist stability criterion, Root locus technique and its application. Concepts of compensation, series/parallel/ series-parallel/feedback compensation, Lag/Lead/Lag-Lead networks for compensation, compensation using P, PI, PID controllers.

ELECTRICAL & ELECTRONIC MEASUREMENTS AND INSTRUMENTATION

Electrical Measurements: Measurements and Instruments: Measurements – Significance, Methods, Types; Instruments – Types, Classification; Functions of Instruments and Measurement Systems; Generalized Measurement System; Application of Measurement Systems. Performance Characteristics of Instruments: Drift, Error, Reproducibility, Repeatability, Noise, Uncertainty, Accuracy, Precision, Resolution, Threshold, Sensitivity, Efficiency, Linearity, Dead Time, Dead Band, Friction, Backlash, Hysteresis, Zero stability, Overshoot, Loading effect. Errors in

Measurement: True value, Types of Error, Error Analysis. Units and Standards: Absolute Units; SI Units – Base Units, Supplementary Units, Derived Units; Standards and their classification (International, Primary, Secondary and Working Standards). Measurement of Resistance, Inductance and Capacitance: Methods of measurement of low, medium and high resistances, Kelvin's double bridge, Wheatstone bridge, Meggers & Ohmmeters, Insulation resistance measurement, Earth resistance measurements, AC bridges for inductance and capacitance measurements, Mutual Inductance measurement, Shielding and Earthing. Measurement of Current and Voltage: Permanent Magnet Moving Coil (PMMC) and Moving Iron (MI) instruments, Electrodynamometer Type & Electrostatic Type Instruments, Measurement of DC / AC voltage and current, Extension of Range, Errors (Both on AC/DC), Multimeter. Instrument Transformers: Current and Potential Transformers, Need & Functions, Construction, Theory, Ratio & Phase Angle Errors and their minimization, Design considerations, Testing of instrument transformers by absolute and comparison methods. Measurement of Power and Energy: Power in DC & AC Circuits; Types of Watt meters; Construction, Operating principle, Torque equation, Shape of scale, Errors, Advantages & Disadvantages of Electrodynamometer type and Induction type Watt meters; Measurement of Power using Instrument Transformers; Measurement of Power in three phase circuits, Three Phase Watt meters, Measurement of Reactive Power; Classification of Energy Meters; Single Phase Induction Type Energy Meter – Construction, Theory & Operation, Errors, Adjustments & Compensation; Three Phase Energy Meters; Maximum Demand Indicator; KVAH & KVARH Metering; Measurement of KVA; Tri-vector Meter; Testing of Energy meters; Meters used for special purposes. Measurement of Phase, Frequency & Speed: Phase (or Power Factor) Meters - Electrodynamometer and Moving Iron types; Frequency Meters – Mechanical Resonance type, Electrical Resonance type, Weston type frequency meters; Phase Sequence Indicator; Synchroscopes; Tachogenerator, Tachometer, Photo-electric meter, Stroboscope. Electronic Measurements: Electronic Voltmeter, Multimeter, Wattmeter & Energy meter; Time, Frequency and Phase Angle measurements; CRO & Special purpose Oscilloscopes; Q-meters; Potentiometric Recorders; Spectrum Analyzer, Wave Analyzer; Harmonic Analyzer; Power Analyzer; Distortion Meter; Digital Voltmeter, Multimeter, Frequency Counter, and Storage oscilloscope; Display Devices - Nixie Tubes, LED, LCD. Instrumentation: Transducers, Classification & Selection of transducers, Thermocouples, Thermisters, LVDT, Strain gauges, Piezoelectric crystal, Use of Transducers in measurement of non-electrical quantities like temperature, pressure, liquid level, flow-rate, displacement, acceleration, noise level etc., Data Acquisition Systems (DAS), A/D and D/A converters.

ANALOG ELECTRONICS

Review of diode and BJT, Bias stabilization: Need for stabilization, fixed Bias, emitter bias, self-bias, bias stability with respect to variations in Ico, VBE & β, Stabilization factors, thermal stability. Bias Compensation techniques. Small signal amplifiers: CB, CE, CC configurations, hybrid model for transistor at low frequencies, RC coupled amplifiers, mid band model, gain & impedance, comparisons of different configurations, Emitter follower, Darlington pair(derive voltage gain, current gain, input and output impedance.)Hybrid -model at high frequencies (π model). Multistage Amplifiers: Cascaded and cascoded amplifiers, Calculation of gain Impedance and bandwidth, Design of multistage amplifiers. Feedback Amplifiers: Feedback concept, Classification of Feedback amplifiers, Properties of negative Feedback amplifiers, Impedance considerations in different Configurations, Examples of analysis of feedback Amplifiers. Field Effect Transistor: Introduction,

Classification, FET characteristics, Operating point, Biasing, FET small signal Model, enhancement & Depletion type MOSFETS. Power Amplifiers: Power dissipations in transistors, Amplifiers Classification, (Class-A, Class-B, Class-C, Class-AB) Efficiency analysis, Push-pull and complementary Push-pull amplifiers, crossover distortion and harmonic distortion in push pull amplifier. Tuned amplifiers. Op-Amp and its applications: Inverting and Non-inverting amplifiers, adder, sub-tractor, integrators, differentiator, instrumentation amplifiers, oscillators, and multi vibrators.

Syllabus of Paper – 2

ELECTRICAL GENERATOR AND AUXILIARIES

Generator Constructional Details : Basic principle of electricity generation, Development of generator design. Hydrogen Cooling System and Stator Water Cooling System: Different types of cooling arrangements for rotor and stator, Selection and properties of coolant, Air cooling, Hydrogen cooling, Stator water cooling, Hydrogen Charging / Purging Cycle. Hydrogen Seal Oil System: Details of the system, Function and purpose of differential pressure regulator and pressure oil regulators, Types of hydrogen seals and their constructional details. Generator Excitation System and AVR: Principles, Simple arrangement of exciter and its field winding, Classification of excitation system and exciter development, High Frequency Excitations System, Static Excitation System, Brushless Excitation system – their merits and demerits, Automatic Voltage Regulator and its control. Transformers: Working Principle, Various types of transformers used in a power station, Constructional features of main transformer and accessories, Bucholtz relay and main protections, Types of cooling, Mulsifire and other fire protection systems. Motors: Fundamentals, Constructional details of HT / LT motors, Various motors used in Power Stations. HT-LT Supply System / DC Supply System: A typical layout of 6.6 KV, 3.3 KV and 415 KV supply system in a TPS, DC supply system in a TPS. Switchyard: A typical layout of Switchyard of a Thermal Power Station, Bus system, Isolators, CTs, PTs, Earthing, Oil Circuit Breakers, Air Blast Circuit Breakers, SF6 Circuit Breakers, Vacuum Circuit Breakers.

POWER SYSTEM PROTECTION AND SWITCHGEAR

Protection System: Importance of protective relaying in power systems; Fundamental requirements of a good protection scheme; Zones of protection, Primary and Back–up Relaying. Protective Relays : Terms used in protective relaying; Classifications of Relays - Constructional / Functional; Electromagnetic Relays – attracted armature, induction disc, induction cup types relays; Overcurrent and Earth fault relays, Directional, Differential, Distance Relays etc.; Principles & Characteristics of relays; Operation, setting, testing and applications, maintenance requirements of relays; Translay relay; Negative Sequence relays; Universal Relay Torque Equation; Electronic relays; Static relays; Digital relays; Microprocessor and PC based relaying. Circuit Interruption: Fuses - Types of fuses, Terms (Fusing factor, Breaking capacity etc.), Fuse selection, HRC fuses and their applications; Arcing phenomena, Essential properties of arc, Initiation and Maintenance of an arc, Arc voltage, Arc interruption theories, Recovery and Restriking voltages, Rate of Rise of Restriking Voltage (RRRV), Resistance Switching, Inductive current chopping, Capacitive current breaking. Circuit Breakers: AC and DC circuit breaking, Types of Circuit Breakers - ACB, OCB, ABCB, SF6CB, VCB; Static Circuit Breakers; Comparative merits and demerits of different types of CBs, Rating of Circuit Breakers, Testing and Selection of Circuit Breakers, Autoreclosing. Power Plant Protection Protection Schemes: Schemes for protection of transmission line; Merz-Price circulating current scheme, Percentage differential relay, Restricted earth fault protection, Negative Sequence protection, Translay scheme, Carrier relaying scheme, Pilot relaying scheme, Static and other relays used in transmission line protection. Generator Protection: Neutral earthing, stator and rotor earth faults, sustained external faults, instability, protective systems. Transformer Protection: Various transformer protections, protective systems for Generator Transformers (GTs), Unit Auxiliary Transformers (UATs) and Station Transformers (STs). Motor Protection: Faults and Protection systems. Busbar Protection: Continuity of supply, Discrimination, Circulating current systems, special features relating

to different voltage systems. Feeder Protection: Continuity of supply discrimination, outline of protection systems – Pilot wire, carrier current, distance protection, PLCC – Telemetry Communication.

POWER PLANT CONTROL AND INSTRUMENTATION

Transducers, Classification, Analog & Digital transducers, Selection of transducers, Strain gauges, Inductive & Capacitive transducers, Piezoelectric and Hall-effect transducers, Measurement of non-electrical quantities like temperature, pressure, liquid level, flow-rate, displacement, velocity, acceleration, noise level etc., Thermisters, Thermocouples, LVDT, Photo-diodes & Photo-transistors, Encoder type digital transducers, Signal conditioning and telemetry. Basic concepts of smart sensors and application, Data Acquisition Systems (DAS), A/D and D/A converters. Concept and layout of Control and Instrumentation in Thermal Power Plant. Measurement & Measuring instruments. Pressure Measurement and measuring instruments, Temperature Measurement and measuring Instruments, Flow measurement and measuring instruments, Level Measurement and measuring instruments. Practical demonstration on pressure, flow, level and temperature measurements, Protection and interlocks of Boiler, Turbine and their auxiliaries. Introduction to auto control, Auto control loops used in thermal power stations. Turbovisory instrumentation (Parameters limits, Basic concepts of measuring devices), Commissioning of control loops – Practical demonstration ATRS, Visit to control and instrumentation lab. and control / control stations in thermal power stations. Analytical Instrumentation for Boiler (Water, Steam, Flue Gas, H_2 / O_2 / CO_2), Practical demonstration and practice on analytical instruments (Correct approach for sampling and testing). Introduction to DDC and DAS in Thermal Power Station, Introduction to new / latest technology in Control and Instrumentation in modern thermal power station.

LOAD DISPATCH AND ELECTRICITY REGULATIONS

Load Dispatch: Overview of power systems communication infrastructure, RTUs, SCADA, PLCC, Communication Systems, Network Protocols. Transfer of Energy in Power Systems, VAR flows, Power System Control, Voltage Control Methods, Load Frequency control-Speed Governing Systems, AGC, frequency limits; Economic load dispatch neglecting losses, Optimum load dispatch including transmission losses. Unit commitment-constraints, spinning reserve, solution methods-Priority list method; Energy management Systems. LDCs-NLDC, SLDC, RLDC etc. Hydrothermal coordination-LR/SR scheduling, models, scheduling problems, dynamic programming solution to scheduling problem. Unit commitment, State Estimation- basics, PS state estimation, ML weighted LSE-concepts, examples Regulatory Issues: Electricity Act 2003-IEA-1910, Electricity Supply Act 1948, Regulatory Commission Act 1998. Transition to Deregulation- Problems in conventional systems, Blackouts-Analysis Reasons for reforms. IEA 2003. Its impact on power Generation, Transmission and Distribution, transmission Open Access, wheeling, power banking concepts. ABT basics, Energy Conservation concepts and DSM basics.

POWER ELECTRONICS AND ELECTRIC DRIVES

Power Electronics: SCR and its characteristics: gate characteristics, SCR ratings, series and parallel connections of SCRs. Triac, GTO, IGBT characteristics and ratings. Unijunction Transistors. Triggering circuits and optocouplers. Linear commutated converters: single pulse, two pulse midpoint, three pulse mid-point and 3 phase six pulse converters. Effect of source inductance on

converters. Freewheeling diode effect. D.C. Choppers – Principles of step down chopper, step up chopper and classification. Impulse commutated and resonant pulse choppers. Multiphase choppers. Application of choppers. Single phase and three phase bridge inverters. Commutation and trigger circuits for forced commutated thirstier inverters. Output voltage control. Harmonies in output voltage waveform harmonics attenuation by filters. Harmonic reduction by pulse width modulation. Working of current source inverters. Switched Mode Power Supplies. Electric Drives: Review of characteristics of A.C. and D.C. Motors, Phase controlled and chopper controlled drive of D.C. motor. Pulse width modulated (PWM) Induction motor drive (voltage source and current source inverters). Digital Control Drive, Stepper Motors, Electrical drives in steel, cement, Textile, paper mills, Machine tool drive and computerized numerical control (CNC).

ELECTROMAGNETIC FIELD THEORY

Introduction: Scalar and vector field, Dot and Cross products, Coordinate Systems-Cartesian, cylindrical and spherical. Vector representation of surface, Physical interpretation of gradient divergence and curl, Transformation of vectors in different co-ordinate systems, dirac-delta function.

Electrostatics: Electric field due to point-charges, line charges and surface charges, Electrostatic potential, Solution of Laplace and Poisson's equation in one dimension, M-method of image applied to plain boundaries, field mapping and conformal transformation, Electric flux density, Boundary conditions. Capacitance: calculation of capacitance for simple rectangular, cylindrical and spherical geometries, Electrostatic energy. Magnetostatics : Magnetic Induction and Faraday's Law, Magnetic Flux Density, Magnetic Field Strength H, Ampere, Gauss Law in the Differential Vector Form, Permeability, Energy Stored in a Magnetic Field, Ampere's Law for a Current Element, Volume Distribution of Current , Ampere's Law Force Law, Magnetic Vector Potential, The Far Field of a Current Distribution, Maxwell's Equations: The Equation of Continuity for Time Varying Fields, Inconsistency of Ampere's Law, Maxwell's Equations, Conditions at a Boundary Surface. Electromagnetic Waves: Continuity equations, Displacement current, Maxwell's equation, Boundary conditions, Plane wave equation and its solution in conducting and non-conducting media, Phasor notation, Phase velocity, Group velocity, Depth of penetration, Conductors and dielectrics, Impedance of conducting medium. Polarization, Reflection and refraction of plane waves at plane boundaries, Poynting vectors, and Poynting theorem. Transmission Lines: Transmission line equations, Characteristic impendence, Distortion-less lines, Input impendence of a loss less line, computation of primary and secondary constants, Open and Short circuited lines, Standing wave and reflection losses, Impedance matching, Loading of lines, Input impedance of transmission lines, RF lines, Relation between reflection coefficient and voltage standing wave ratio (VSWR), Lines of different lengths – $\lambda/2$, $\lambda/4$, $\lambda/8$ lines, Losses in transmission lines, Smith chart and applications, impedance matching Single stub, Double stub.

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