M. TECH. I-SEMESTER

1MPS1 POWER SYSTEM ANALYSIS

Fault Analysis: Positive, Negative and Zero sequence equivalent circuits of lines, two and three winding transformers and synchronous machines. Analysis of shunt and series faults, effect of neutral grounding.

Admittance and Impedance Model and Network Calculations: Calculation of Z-bus, Y-bus. Algorithm for the formation of bus admittances and impedance matrices, Fault calculation using Z-bus.

Load Flow Studies: Formulation of load flow problem. Various types of buses. Gauss-Siedel, Newton-Raphson and Fast Decoupled Algorithms.

Calculation of reactive power at voltage controlled buses in the Gauss-Siedel interactive method using Y-bus. Representation of transformers-Fixed tap setting transformer, Tap changing under load transformers, Phase shifting transformers, Comparison of methods for load flow.

Power System Security and State Estimation: Concepts of security states and security analysis in power system, State estimation in power system.

1MPS2 ADVANCED POWER ELECTRONICS

Phase Controlled Converters: Performance measures of single and three-phase converters with discontinuous load current for R, RL and RLE loads. Effect of source inductance for single and three-phase converters.

Chopper-Review of choppers configurations, Steady state analysis of type A Chopper-Minimum and Maximum Currents, Ripple and average load current. Commutation in Chopper Circuits.

Inverters: Performance parameters, voltage control of three phase inverters-Sinusoidal PWM, Third Harmonic PWM, 60 degree PWM and Space Vector Modulation. Harmonic reductions

AC Voltage Controllers: Single and Three Phase AC Controllers. AC Voltage Controller with PWM Control.

Cyclo-converters: Single phase and three phase Cyclo-converters. Reduction in Output Harmonics. Matrix Converter

1MPS3 POWER SYSTEM STABILITY

Synchronous Machines: Modelling of cylindrical rotor synchronous machine, flux linkage equations, voltage equations and equivalent circuit, real and reactive power control. Modelling of salient pole synchronous machine (Two – axis model), flux linkage equations, Park's transformation, current and voltage equations.

Transient and subransient effects, reactances and time constants of synchronous machines. Equivalent circuits, vector diagrams, power angle equations and characteristics under steady state and transient conditions.

Steady State and Dynamic Stabilities: Development of swing equation, linearisation of swing equation. Steady state stability of single machine connected to an infinite bus system and two machine systems. Coherent and non-coherent machines. Swing equation including damping effect. Introduction to dynamic stability of power system. Introduction to classical model of multi machine system.

Transient Stability: Equal area criterion and its application to transient stability studies under common disturbances including short circuits. Critical clearing angle and critical clearing time.

Numerical solution of swing equation by step-by-step method.

(i) Multi machine Transient Stability: Numerical methods for solution of differential equations: Modified Euler Method, Runge – Kutta fourth order method. Multi machine transient stability studies using modified Euler method and Range – kutta fourth order method. **(ii)** Factors affecting steady state and transient stabilities. Methods of improving steady state, dynamic and transient stabilities, series capacitor compensation of lines, excitation control, power stabilizing signals, High speed circuit breaker, auto – recolsing circuits breaker, single pole and selective pole operation, by pass valving and Dynamic braking.

1MPS4.1 POWER GENERATION SOURCES

World energy situation. Indian energy scene. Comparative study of thermal, hydro, nuclear and gas power plants. Selection and location of power plants. Impact of thermal, gas, hydro and nuclear power stations on environment, air and water pollution, green house effect (global warning), impact on land. Renewable and non-renewable energy sources. Conservation of natural resources and sustainable energy sources.

Efficiency improvement of thermal and gas power plants- pressurized fluid bed combustion of coal, combined gas steam plant and cogeneration.

Solar Energy: Solar radiation, solar radiation geometry, solar radiation on tilted surface. Solar energy collector. Flat- plate collector, concentrating collector – parabolidal and heliostat. Solar pond. Basic solar power plant. Solar cell, solar cell array, basic photovoltaic power generating system.

(i) Wind Energy: Basic principle of wind energy conversion, efficiency of conversion, site selection. Electric power generation-basic components, horizontal axis and vertical axis wind turbines, towers, generators, control and monitoring component

ts. Basic electric generation schemes- constant speed constant frequency, variable speed constant frequency and variable speed variable frequency schemes. Applications of wind energy.

(ii) Geothermal Energy: Geothermal fields, estimates of geothermal power. Basic geothermal steam power plant, binary fluid geothermal power plant and geothermal preheat hybrid power plant. Advantages and disadvantages of geothermal energy. Applications of geothermal energy. Geothermal energy in India.

Nuclear Fusion Energy: Introduction, nuclear fission and nuclear fusion. Requirements for nuclear fusion. Plasma confinement - magnetic confinement and inertial confinement. Basic Tokamak reactor, laser fusion reactor. Advantages of nuclear fusion. Fusion hybrid and cold fusion.

Biomass Energy: Introduction, biomass categories, bio-fuels. Introduction to biomass conversion technologies. Biogas generation, basic biogas plants-fixed dome type, floating gasholder type, Deen Bandhu biogas plant, Pragati design biogas plant. Utilization of biogas. Energy plantation. Pyrolysis scheme. Alternative liquid fuels –ethanol and methanol. Ethanol production.

1MPS4.2 ECONOMIC OPERATION OF POWER SYSTEM

Economics of Power Generation: Introduction, cost of electrical energy, expression for cost of electrical energy, depreciation, power plant cost analysis, economics in plant selection, selection of types of generation and types of equipments, factors effecting economic generations and distributions, generating cost, economics of different types of generating plants.

Economical Operations of Thermal Power Plants: Generator operating cost, input, output curves, heat rate and incremental rate curves of generating units, system constraints, economic dispatch problem, economic dispatch using Newton Raphson method, classical method, Calculation of loss coefficient using Y_{bus}, using Sensitivity Factors: Generation Shift Distribution (GSD) factors, Generalised Generation shift Distribution (GGSD) Factors.

Effects of transmission losses, transmission loss coefficients, formula, function of generation and loads, economic dispatch using exact loss formula which is function of real and reactive power, economic dispatch for active and reactive power balance, evaluation of incremental transmission loss, economic dispatch based on penalty factors.

Economical Operations of Hydrothermal Power Plants: Classification of hydro plants, long-range problem, short-range problem. Hydro Plant performance Model, Glimn-Kirchmayer Model, Hamilton-Lamonts Model, thermal and hydro model for short range fixed head hydrothermal scheduling, equality and inequality constraints, transmission losses, advantages of combined operation, base load, peak load operation requirement, Newton Raphson method for short range fixed head hydrothermal scheduling, reservoir dynamics, equality and inequality constraints, idea of multiobjective generation scheduling.

Interconnected System: Merits and demerits, parallel operation of alternators, synchronizing current, power & toque, effect of change of excitation, driving torque & speed of one of the alternators, load sharing and power limit of interconnected stations, voltage, frequency& load control of interconnected stations.

1MPS4.3 NUMERICAL METHODS & COMPUTER PROGRAMMING

Matrix Algebra: (a) Matrix Computation: Algebra of matrices, Inverse of a matrix, Rank of a matrix. Matrix inversion by Gauss elimination method, Computer programs for matrix computation using MATLAB. **(b) Eigen values and Eigen Vectors:** Characteristic equation of a matrix, Determination of eigen values and eigen vectors, Cayley Hamilton theorem, Largest and smallest eigen values, Computation of eigen values and eigen vectors using MATLAB.

Solution of Linear and Non Linear Equations: (a) Solution of linear equations: Crammer's rule, consistency of linear simultaneous equations, Gauss elimination method, Gauss Jordan elimination method. Gauss-seidal iterative method. Computer program for the solution of linear equations using MATLAB. **(b) Solution of Non-Linear Equations:** Interval bisection method, Secant method, Regular falsi method, Newton-Raphson method. Solution of non-linear equations using MATLAB.

Numerical Differentiation and Integration: (a) Numerical differentiation using Newton's forward, backward and Stirling's interpolation formulae. **(b) Numerical Integration:** General quadrature formula, Trapezoidal rule, Simson's rule, Simpson's three eight rule, Romberg integration. Numerical integration program using MATLAB.

Solution for Differential Equations: Euler's method, Improved Euler's method, Runga-Kutta method of second order. Runga-Kutta method of fourth order. Solution of differential

equations using MATLAB.

Programming in MATLAB: Basics of MATLAB, Matrices and vectors, Matrix and array operations, Saving and loading data, Plotting simple graphs, Scripts and functions, Script files, Function files, Global variables, Loops, Branches, Control flow, Advanced data objects, Multi-dimensional matrices, Structures, Applications in linear algebra, Curve fitting and interpolation, Numerical integration, Ordinary differential equations, Non-linear algebraic equations.

1MPS5 MATLAB PROGRAMMING LAB

1 Basics of MATLAB matrices and vectors, matrix and array operations, Saving and loading data, plotting simple graphs, scripts and functions, Script files, Function files, Global Variables, Loops, Branches, Control flow, Advanced data objects, Multi-dimensional matrices, Structures, Applications in linear algebra curve fitting and interpolation. Numerical integration, Ordinary differential equation. (All contents is to be covered with tutorial sheets)

2 **Simulink:** Idea about simulink, problems based on simulink. (All contents is to be covered with tutorial sheets)

M. TECH. II- SEMESTER

2MPS1 ELECTRIC DRIVES & THEIR CONTROL

Characteristics of Electric Motors: Characteristics of DC motors, 3-Phase induction motors and synchronous motors, Starting and braking of electric motors. **Dynamics of Electric Drives:** Mechanical system, Fundamental torque equations, components of load torque's, Dynamic conditions of a drive system, Energy loss in transient operations, Steady State Stability, Load equalization.

DC Motor Drives: Starting, Braking and Speed Control, Transient analysis of separately excited motor with armature and field control, Energy losses during transient operation, Phase controlled converter fed DC drives, Dual-converter control of DC drive, Supply harmonics, Power factor and ripple in motor current, Chopper Control DC drives, Source current harmonic in Choppers.

Induction Motor Drives: Starting, Braking and transient analysis, Calculation of energy losses, Speed control, Stator voltage control, Variable frequency control from voltage and current sources, Slip power recovery-Static Scherbius and Cramer drives.

Synchronous Motor Drives: Starting, Pull in and braking of synchronous motors, Speed control – variable frequency control, Cycloconverters control. Brushless DC Motor, Linear Induction Motor, Stepper Motor and Switched Reduction Motor Drives: Important features and applications.

Energy Conservation in Electrical Drives: Losses in electrical drive system, Measures for energy conservation in electric drives, Use of efficient motor, Energy efficient operation of drives, Improvement of power factor and quality of supply.

2MPS2 ADVANCED POWER SYSTEM PROTECTION

(i) Static Relays: Introduction, merits and demerits of static relays. **Comparators:** amplitude and phase comparator, duality between amplitude and phase comparators. Circulating current type phase-splitting type and sampling type amplitude comparators. Vector product type and coincidence type phase Comparators. **(ii) CTs & PTs:** Current transformer (CT) Construction, measurement CT and protective CT. Type of potential transformers. Steady state ratio and phase angle errors in CTs and PTs. Transient errors in CT and CVT.

(i) Static Over Current Relays: Instantaneous over current relay, definite time over current relay, inverse-time over current relay, directional over current relay.

(ii) Static Differential Relays: Differential relay scheme, single-phase static comparator, polyphase differential protection. Differential protection for generator and transformer.

(i) Static Distance Relays: Impedance relay, reactance relay and mho relay using amplitude and phase comparators. Polarized and offset mho relays.

(ii) Carrier Current Protection: Phase Comparison scheme, carrier aided distance protection.

(i) Distance Protection: Effect of are resistance, power swings, line length and source impedance on the performance of distance protection. Out of step tripping and blocking relays. Mho relay with blinders. Quadrilateral and elliptical relays. Selection of distance relays.

(ii) Induction Motor Protection: Various faults and abnormal operating conditions. Protection against faults, unbalance supply voltage, single phasing, over load and mechanical rotor faults, HRC fuses, over-current, percentage differential and earth fault protection. Negative sequence voltage relays and resistance temperature detector relay.

Digital Protection: Introduction to digital protection, block diagram of digital relay, sampling theorem, correlation with a reference wave, Fourier analysis of analogue and discrete signals, least error squared technique, digital filtering – low pass, high pass, finite impulse response and infinite impulse response fillers. Introduction to digital over-current, transformer differential and transmission line distance protection.

2MPS3 EHV AC/DC TRANSMISSION

Bulk power transmission over long distance, Need for EHV transmission, Problem of EHV transmission power handing capacity and surge impedance loading, Current carrying capacity of conductor, Choice of economic voltage.

Bundled Conductors: Properties of bundled conductors, Geometric mean radius of bundle, Inductance and capacitance, Voltage gradients of conductors, Maximum surface voltage gradients of bundled conductors, Comparison of maximum surface electric fields for bundled and single conductor lines, Electrostatic fields of EHV lines. Effect of ES fields of humans, Animals and plants.

Series and Shunt Compensation: Effect of series capacitors, Location of series capacitors. Sub-synchronous resonance in series-capacitor compensated lines and counter measures, Shunt compensation-variation of no load receiving end voltage. Static VAR systems: TCR, TCR-FC, TSC-TCR and MSC-TCR schemes

HVDC Transmission: HVDC transmission, kind of dc links, light activated thyristor, series and parallel connection of thyristors. Scheme of converter station, 12 – pulse convecter, converter unit, converter operation, fitters, reactive power source, ground return and ground electrode.

HVDC Link: Control of HVDC link, Converter control characteristics, firing angle control and extinction angle control. Comparison between AC and DC transmissions Applications of

HVDC transmission. Power modulation and power control of HVDC lines.

2MPS4.1 OPERATION & CONTROL OF POWER SYSTEMS

Optimal Power System Operation: System constraints. Generator operating cost. Input-Output and incremental fuel characteristics of a generating unit. Optimal operation of generators on a bus bar, algorithm and flow chart. Optimal unit commitment, constraints in unit commitment, spinning reserve, thermal and hydro constraints.

Unit Commitment Solution Methods: Priority list method and dynamic programming method. Reliability consideration, Patton's security function, security constrained optional unit commitment, start- up considerations.

Optimal Generation Scheduling: Development of transmission loss and incremental loss equations. Optimal generation scheduling including transmission losses, algorithm and flow chart. Optimal load flow solution. Hydrothermal coordination.

Load Frequency Control: Control of real and reactive power of generator. Turbine speed governing system, Modelling of speed governing system. Methods of frequency control: flat frequency, flat tie line and tie line load bias control. Block diagram representation of load frequency control of an isolated system, steady state analysis, dynamic response. Introduction to Two – area load frequency control.

(i) Power System Security: Introduction to power system security, System monitoring, contingency analysis, System state classification, security control.

(ii) Automatic Generation Control: Speed governing characteristic of a generating unit. Load sharing between parallel operating generators. Introduction to automatic generation control of an area by computer (description of block diagram).

2MPS4.2 POWER SYSTEM DYNAMICS

Dynamic models of synchronous machines, Excitation system, Turbines, Governors, Loads.

Modelling of single machine infinite bus system, Mathematical Modelling of multi-machine system.

Dynamic and transient stability analysis of single machine and multi-machine system.

Power system stabilizer design for multi-machine system.

Techniques for the improvement of stability.

2MPS4.3 POWER SYSTEM PLANNING & RELIABILITY

Load Forecasting: Classification and characteristics of loads, Approaches to load forecasting, Forecasting methodology, Energy forecasting.

Basic Probability Theory: Review of probability concepts, Probability distribution, Application of binomial distribution to engineering problem, Probability distribution in reliability evaluation, Network modeling and evaluation of simple and complex systems, System reliability evaluation using probability distribution, Frequency and duration methods.

Generation System Reliability Evaluation: Concept of LOLP, Evaluation of indices for isolated system, Generation system, Reliability analysis using the frequency and duration methods.

Transmission System Reliability Evaluation: Evaluation of LOLP and indices for an isolated transmission system using frequency and duration method.

Distribution System Reliability Evaluation: Reliability analysis of radial system with perfect and imperfect switching.

2MPS5 POWER SYSTEM MODELLING & SIMULATION LAB

1 Simulate Swing Equation in Simulink (MATLAB)

2 Modelling of Synchronous Machine.

3 Modelling of Induction Machine.

4 Simulate simple circuits using Circuit Maker.

5 (a) Modelling of Synchronous Machine with PSS (b) Simulation of Synchronous Machine with FACTS device.

6 (a) Modelling of Synchronous Machine with FACTS device (b) Simulation of Synchronous Machine with FACTS devices.

7 FACTS Controller designs with FACT devices for SMIB system.

3MPS1.1 FLEXIBLE AC TRANSMISSION SYSTEMS

Problems of AC transmission systems, power flow in parallel paths and meshed system, factors limiting loading capability, stability consideration. Power flow control of an ac transmission line. Basic types of facts controllers. Advantages of FACTS technology.

(i) Voltage-Sourced Converters: Basic concept of voltage-sourced converters, single and three phase bridge converters. Introduction to power factor control. Transformer connections for 12- pulse, 24 pulse and 48 pulse operations. **(ii) Static Shunt Compensators:** Mid point and end point voltage regulation of transmission line, and stability improvement. Basic operating principle of Static Synchronous Compensators (STATCOM). Comparison between STATCOM and SVC.

Static Series Compensators: Concept of series capacitive compensation, voltage and transient stabilities, power oscillation and subsynehronous oscillation damping. Introduction to thyristor- switched series capacitor (TSSC), thyristor controlled series capacitor (TCSC), and static synchronous series compensator-operation, characteristics and applications.

(i) Static Voltage and Phase Angle Regulators: Voltage and phase angle regulation. Power flow control and improvement of stability by phase angle regulator. Introduction to thyristor controlled voltage and phase angle regulators (TCVR and TCPAR)

(ii) Introduction to thyristor controlled braking resistor and thyristor controlled voltage limiter.

(i) UPFC: Unified Power Flow Controller (UPFC), basic operating principles, conventional transmission control capabilities. Comparison of UPFC to series compensators and phase angle regulator. Applications of UPFC. **(ii) IPFC:** Interline Power Flow Controller (IPFC), basic operating principles and characteristics. Applications of IPFC.

3MPS1.2 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

Thyristor Valve: Thyristor device, Steady state and switching characteristics, Light activated power thyristor, LED, fiber optics, valve firing, parallel and series connections of thyristors. Converter Circuits: Rectification and inversion, effect of reactance, six pulse and twelve pulse converter circuits.

DC Link Control: Principles of DC link control, Converter control characteristics, System control hierarchy, Firing angle control, Extinction angle control, Starting, stopping and power flow reversal of DC link, Power control, Parallel operation of DC link with AC transmission line.

Converter faults, commutation failure, valve blocking and bypassing. Protection against over currents, over voltages. DC circuit breakers. Reactive Power Control: Reactive power

requirement in steady state, Sources of reactive power and reactive power control.

(i)Harmonic and Filters: Generation of harmonics, AC and DC side harmonics, characteristics and non-characteristics harmonics. Types of AC filters – single tuned and double tuned filters, high pass filter, DC Smoothing reactor and filters.

(ii) Scheme of a HVDC converter station and components of HVDC transmission system.

Multi Terminal DC (MTDC) Systems: Types of MTDC systems, Comparison of series and parallel MTDC systems, Control and protection of MTDC systems, Application of MTDC systems.

3MPS1.3 POWER SYSTEM TRANSIENTS & HIGH VOLTAGE ENGINEERING

Wave terminology, Development of wave equations, Terminal problems, Lattice diagrams, Origin and nature of power system transient and surges, Surge parameters of plants, Equivalent circuit representations, Lumped and distributed circuit transients, Line energisation and de-energisation, Earth and earth wire effect.

Current chopping in circuit breakers, Short line fault condition and its relation to circuit breaker duty, Trapped charge effect, Effect of source and source representation in short line fault studies.

Control of transients, Lightening phenomenon, Influence of tower footing resistance and earth resistance, Traveling waves in distributed parameters multi-conductor lines, Parameters as a function of frequency.

Methods of neutral grounding and their effect on system behavior, Insulation coordination, Over voltage limiting devices, Dielectric properties, Requirement in surge protection of lines and equipments.

Impulse generator development, Impulse-testing technique, Power frequency HV Transformers, Cascade connection, HVDC Generators, Tests with power frequency and DC voltage, Large current generating and measurement techniques, Partial discharge testing, High voltage and high current testing of power equipment.

3MPS2.1 ADVANCED POWER SYSTEM

Voltage Stability: Power system voltage stability concept, comparison of angle and voltage stabilities, Power system loads, generator P-Q and Q-V characteristics. Voltage collapse. Voltage stability analysis. Methods of improving voltage stability.

Distribution Automation: Introduction to distribution automation. Concepts of communication - power line carrier, radio communication, fibre optics, satellite communication and sensors. Introduction to supervisory control and data acquisition (SCADA). Brief description of an automation system.

FACTS: Problem of AC transmission systems, basic principle of power flow control of an AC transmission line. Basic types of FACTS controllers. Brief description of FACTS controllers-STATCOM, Static Voltage and phase angle regulators, thyristor switched and thyristor controlled series capacitors, Unified Power Flow Controller.

Energy Conservation: Introduction, conservation of natural resources, principles of energy conservation and energy audit. Brief description of energy conservation in power plants, electric utilities, electric drives, industries and electric lighting.

Superconductivity: Basic characteristics of superconductors. Brief description of applications of superconductivity to electric power systems - superconducting generators, motors, transformers, transmission cables and magnetic storage.

3MPS2.2 EXCITATION OF SYNCHRONOUS MACHINES & THEIR CONTROL

Excitation Systems: Real and reactive power control of a generating unit, loading capability diagram, reactive capability limits. Excitation system requirements, elements of an excitation system, types of excitation systems.

i) DC Excitation System: Configuration of a DC excitation system with main and pilot exciters, automatic voltage regulator with magnetic amplifier and amplidyne. Limitations and problems of DC excitation systems. **(ii) AC Shunt Excitation Systems:** AC shunt excitation system with static thyristor converter, effect of faults on performance, use of booster (current) transformer. Advantages, problem and application of AC shunt excitation systems.

(i) AC Separately Excitation Systems: Configurations of AC separately excitation system with (a) diode rectifier and (b) thyristor converter. Comparison and application of these schemes. **(ii) Brushless Excitation System:** Brush–slip ring problem. Scheme of brushless excitation system with rotating diode. Control protection, monitoring and application of brushless excitation systems.

(i) Introduction to super conducting synchronous generator. **(ii) Dynamic Performance Measures:** Introduction, large signal and small signal performance measures. **(iii) Control and Protective Functions:** Basic excitation system control and protective circuit, AC and DC regulator, power system stabilizer (PSS) and stabilizing circuit, load compensations, limiters and protection.

(i) Modelling of Excitation Systems: Per unit system for exciter. Introduction to modelling of DC and AC Exciters. **(ii)** Effect of excitation control on steady state, dynamic and transient stabilities.

3MPS2.3 AI APPLICATIONS TO POWER SYSTEMS

Introduction to AI: Definition, Applications, Components of an AI program; production system, Problem characteristics, Overview of searching techniques. Knowledge representation: Turning test, AI agents and architecture, Predicate and propositional logic, Procedural versus declarative knowledge, forward versus backward reasoning.

Statistical Reasoning: Probability and Baye's theorem, Certainty factor and rule based systems, Baysian Networks, Dampster Shafer theorem, Examples of knowledge based systems.

Artificial Neural Networks: Biological Neuron, Neural Net, Use of neural nets, Applications, Perceptron Model, Idea of single layer and multiplayer neural nets, Back propagation, Hopfield nets, Supervised and unsupervised learning.

Expert Systems: Introduction, Study of some popular expert systems, Expert system building tools and shells, Components of expert systems, Applications to power systems.

Fuzzy Logic: Fuzzy logic concepts, Fuzzy relation and membership functions, Defuzzufication, Fuzzy controllers Genetic algorithm: concepts, coding, reproduction, crossover, mutation, scaling and fitness.