Contents

B. Tech

3rd year

B.TECH. III (ELECTRICAL), SEMESTER – V

EE 301 : ELEMENTS OF POWER SYSTEMS

- **SUPPLY SYSTEMS** **(04 Hours)**

  AC and DC power supply systems, comparison of ac and dc transmission, advantages of high transmission voltage, various systems of power supply, comparison of conductor materials in overhead system and underground cable system, economic choice of conductor size and economic choice of voltage.

- **D.C. AND A. C. DISTRIBUTION** **(06 Hours)**

  Types of dc distributors, dc distribution calculations, ac distributor, fed at one and fed at both the ends with concentrated loads and uniformly distributed loads, ring distributors with inter connectors, current distribution in three wire and four wire ac systems, overview of distribution automation.

- **MECHANICAL ASPECTS OF OVERHEAD LINES** **(08 Hours)**

  Main components of over head lines, conductor materials, line supports, insulators, types of insulators, potential distribution over suspension insulators, string efficiency, methods of improving string efficiency, corona, factors affecting corona, important terms, advantages and disadvantages of corona, sag in over head lines and sag calculations.

- **UNDERGROUND CABLES** **(05 Hours)**

  Underground cables, construction of cables, classification of cables, cables for three phase services, insulation resistance of a single core cable, capacitance of a single core cable, dielectric stresses in a single core cable, most economical conductor size in a cable, grading of cables, capacitance grading and inter-sheath grading, capacitance of three core cable and measurements of capacitances.

- **ELECTRICAL DESIGN OF OVERHEAD LINES** **(08 Hours)**

  Conductors, types of conductors in use, bundled conductor, spacing of conductors, symmetrical and unsymmetrical spacing, equivalent spacing, transposition, transmission line constants, calculation of resistance, inductance and capacitance for simple arrangements and multi-circuit lines, symmetrical and unsymmetrical spacing, concept of self GMD, mutual GMD and their uses in calculations of parameters of overhead lines, skin and proximity effects.

- **CHARACTERISTICS AND PERFORMANCE OF POWER TRANSMISSION LINES** **(08 Hours)**

  Short and medium transmission lines, Line performance, effect of capacitance, charging currents, short and medium lines, calculation by nominal-T, nominal-π and end-condenser method, regulation and efficiency, Concept of ABCD constants, the long transmission line- rigorous solution, evaluation of ABCD constants, interpretation of long line equation, surge impedance and surge impedance loading, the equivalent circuit of a long transmission line, power flow through a transmission line, circle diagrams, Ferranti effect.

- **ECONOMIC ASPECTS OF POWER SYSTEM** **(03 Hours)**

  Cost of Generation and Tariff, Power factor and its effect on system economy, Power factor improvement

Total Hours:42

REFERENCES:

1. W. D. Stevenson , “Element of Power System Analysis”, Mc Graw Hill, 1982.
2. Nagrath & kothari, “ Power System Engineering”, TMH publishing Company Ltd.
3. S.L.Uppal, “Electric Power”, Khanna Publisher, 1998.
4. A.Chakrabarti, M.L.Soni, P.V.Gupta, & U.S.Bhatnagar, “A Text Book on Power System Engineering”, Dhanpat Rai & Co., 2001
5. C.L.Wadhwa, “Electric Power System”, New Age International Ltd.
6. Ashfaq Hussain , “Electric Power System”, CBS Publisher & Distributors, 2000

B.Tech. III (Electrical), Semester – V

EE 303: **CONTROL SYSTEMS**

- **INTRODUCTION TO CONTROL SYSTEMS:** **(02 Hours)**

  Open loop control and close loop control; Illustrative examples of control systems.

- **MATHEMATICAL MODELS OF PHYSICAL SYSTEMS:** **(10 Hours)**

  Linear and non-linear systems; equations and transfer functions for linear mechanical translational systems and linear electrical network; Force-Voltage and Force-Current analogy; Block diagram representation of control systems; Block diagram reduction; Transfer functions of armature-controlled and field-controlled DC servomotors and 2-phase AC servomotors; Signal flow graph and Mason's gain formula.

- **TIME DOMAIN ANALYSIS OF CONTROL SYSTEMS:** **(06 Hours)**

  Typical test signals; Response of first-order systems; Transient response of a second order system due to step input; Time domain specifications of a second order system; Impulse and ramp response of second order system; Steady-state errors; Static error coefficients; Error series and dynamic error coefficients.

- **ROOT LOCUS TECHNIQUES:** **(06 Hours)**

  Basic Properties of Root Loci; Construction of Root Loci; Effects of Adding Poles and Zeros

- **CONCEPTS OF STABILITY:** **(02 Hours)**

  Introduction to stability, definition through impulse response function, asymptotic stability and relative stability, Routh-Hurwitz stability criterion.

- **FREQUENCY DOMAIN ANALYSIS OF CONTROL SYSTEMS:** **(08 Hours)**

  Steady state response of a system due to sinusoidal input; Frequency response; Logarithmic plots or Bode diagrams; Log-magnitude versus phase plots; Resonant peak and resonant frequency of a second order system; Polar plots; conformal mapping, principal of argument, Nyquist stability criterion, Stability analysis; Relative stability; Gain margin and phase margin; Closed loop frequency response.

- **DESIGN OF CONTROL SYSTEMS:** **(08 Hours)**

  Introduction to phase lag, phase lead and phase lag-lead networks and their applications. P, PI, PID Controllers.

Total Hours: 42

LIST OF EXPERIMENTS:

1. To obtain open loop and close loop transfer function for an oven.
2. To obtain transfer function of A.C. Servo Motor.
3. To obtain characteristics of Phase lead compensators
4. To obtain characteristics of Phase lag compensators.
5. To study the effect of change in damping factor on transfer function
6. To tune a system with PID controller.
7. a) To obtain time domain parameters of a second order electromechanical system using MATLAB Simulink. b) To obtain 1) Bode plot 2) Root locus 3) Nyquist plot using MATLAB.
8. To design a PID controller for a DC motor using MATLAB
9. To obtain transfer function of D.C Servo Motor.
10. Design a circuit to act as an inverter, summer and a scale changer using Op-amps.

REFERENCES:

1. Nagrath & Gopal, "Control system engineering", New Age International Publishers, 3rd Edition, 2001.
2. K. Oggata, "Modern control system engineering", Pearson Education Asia, 4th Edition, 2002.
3. B.C.Kuo, "Automatic control system", Prentice Hall of India, 7th Edition, 1995.
4. Richard C Dorf & Robert H Bishop, "Modern control system", Pearson Education Asia. 8th Edition, 2004.
5. Nise N. S. John willey & sons, "Control System Engineering", 4th Edition, 2004

EE 305: ELECTRICAL MEASUREMENTS

- **STANDARDS** **(03 Hours)**

  Standards and their classification. Electrical Standards: EMF, current, resistance and capacitance standards

- **POTENTIOMETERS** **(04 Hours)**

  Construction, operation, standardization and application of DC and AC potentiometers, VR box.

- **MEASUREMENT OF RESISTANCE** **(06 Hours)**

  Classification of resistances, Kelvin's double bridge, Whetstone's bridge, Carey Foster's bridge, direct deflection method and loss of charge method for measurement of insulation resistance, meg-ohm bridge, measurement of surface resistivity, earth résistance.

- **MEASUREMENT OF INDUCTANCE AND CAPACITANCE** **(07 Hours)**

  General four arm AC bridge network, Maxwell, Hay, Anderson, Schering and Wien bridge networks, Wagner earthling device, headphone and vibration galvanometer as detector

- **MAGNETIC MEASUREMENTS** **(06 Hours)**

  Theory and calibration of ballistic galvanometer; use of it for measurement of flux, Grassot flux meter, Hall effect devices for measurement of flux, measurement of iron loss by wattmeter method, Hibbert magnetic standard.

- **INDICATING AND INTEGRATING INSTRUMENTS** **(09 Hours)**

  Classification, operating principles, general construction details of indicating instruments, balancing, control and damping method, theory and construction of PMMC, moving iron electrostatic and rectifier instruments, measurement of high voltage AC and DC and impulse voltage, electrodynamics wattmeter , induction energy meter

- **INSTRUMENT TRANSFORMERS** **(07 Hours)**

  Theory of current and voltage transformer, ratio error and phase angle ,burden, turns compensation performance characteristics , testing and applications of CT and PT

Total hours: 42

LIST OF EXPERIMENTS:

1. Kelvin's Double Bridge
2. Anderson Bridge
3. Calibration of voltmeter using Potentiometer
4. Schering Bridge
5. Calibration of 1-phase energy meter
6. Calibration of 3phase energy meter
7. Current Transformer Testing using Biffi's method
8. Lloyd fisher square

REFERENCES:

1. Golding and Widdis, "Electrical measurements & Measuring instruments", Wheeler books, 5th edition
2. A. K . Sawhney, "Electrical and electronic Measurements and Instrumentation", Dhanpat Rai & co.,17th edition
3. R. K. Rajput, "Electrical and Electronic Measurements and Instrumentation", S. Chand & Company Ltd., 1st Edition.2008.

EE 307: MICROPROCESSORS & MICRO CONTROLLERS

- **REVIEW OF DIGITAL LOGIC CONCEPTS (02 Hours)**

  Number systems, gates & De-Morgan's equivalents, 3-state logic gates, flip-flops, buffers, decoders, encoders, multiplexers, de-multiplexers.

- **MICROPROCESSOR SYSTEM ARCHITECTURE (06 Hours)**

  Introduction, Registers, concept of address and data buses, system control signals, basic bus timing, memory (RAM, ROM), input output devices, Microcomputer systems, over view of 8-16-32 bit microprocessors family.

- **INTRODUCTION TO 8085A MICROPROCESSOR ARCHITECTURE (05 Hours)**

  Introduction to 8085A, pin diagram and pin description, bus timing and instruction timing, de-multiplexing of buses, generation of control signals, concept of interrupts.

- **MEMORY INTERFACING WITH 8085A (04 Hours)**

  Different types of memory, memory map, address decoding scheme for different memory, memory timings.

- **INPUT OUTPUT DEVICES INTERFACING WITH 8085A (04 Hours)**

  Basic interfacing concepts**,** peripheral I/O interfacing and memory mapped I/O interfacing, interfacing of 7 segment LED display, keys, relays, interfacing of programmable devices like 8255, 8254.

- **THE 8051 MICROCONTROLLER ARCHITECTURE (08 Hours)**

  Introduction, 8051 family microcontrollers, hardware architecture, input/output pins, I/O ports and circuits, on chip ram ,general purpose registers ,special function registers, timers-counters, concepts of interrupts.

- **ASSEMBLY LANGUAGE PROGRAMMING OF 8051 (13 Hours)**

  Concept of IDE (assembler, compiler, linker, de-bugger), addressing modes, data move instructions, arithmetic and logical instructions, jump, loop and call instructions, concepts of subroutines, interrupt service routine.

Total hours: 42

LIST OF EXPERIMENTS:

1. Addition and subtraction of bytes
2. Memory Block Movements (Forward, reverse, overlapping)
3. Operation on arrays
4. Multiplication and Division of Signed and Unsigned Numbers
5. Ascending and descending arrangement of data string.
6. Code conversion. (Hexadecimal, BCD, Binary, ASCII etc.)
7. Interrupt driven real time clock with 8085 (combination of interrupt, timer)
8. Program exercises based on delay and subroutines.
9. Program exercises based on 8255 peripheral.

References:

1. R.S.Gaonker, "Microprocessor Architecture, programming, and application", wiley eastern limited
2. Kenneth J. Ayala, "The 8051 Microcontroller", Penram International 3rd edition
3. M. Mazidi and others, "The 8051 Microcontroller and Embedded Systems", PRENTICE Hall Of India, 3rf edition
4. Michael slater, "Microprocessor based Design", PRENTICE Hall Of India, 3rd edition
5. Badri Ram, "Fundamentals of microprocessors and microcomputers", Dhanpat Rai.

B. Tech. III (EC) Semester V

EC 311: NEURAL NETWORKS & FUZZY LOGIC

• **INTRODUCTION (07 Hours)**
Introduction to ANN, Basic Concepts, Structure And Function Of Biological Neutron, Perceptron, Multilayer Network

• **NETWORK LEARNING (12 Hours)**
Biases And Thresholds, Delta Rule, Linear Discriminate Functions, Least-squares Techniques, Adaline, Fisher's Linear Discriminate Supervised Learning, Feed-Forward Network, Back-Propagation Algorithm, Unsupervised Learning, Learning Vector Quantizers, Associative Learning Rules, The Hopfield Net

• **MULTILAYER NETWORKS (16 Hours)**
Radial Basis Function Network, Competitive Learning, Self Organizing Network, Principle Component Analysis, Recurrent Network

• **BASIC CONCEPETS OF FUZZY LOGIC (10 Hours)**
Fuzzy Sets And Relations, Linguistic Descriptions And Their Analytical Forms, Fuzzy Algorithm Inference And Composition, Fuzzy Approaches To Engineering Problems

(Total Contact Time: 45 Hours)

BOOKS RECOMMENDED:
1. Haykin Simon, "*Neural Networks: A Comprehensive Foundation"*, McGraw-Hill, 2nd Ed. 1995
2. Mehrotra, Chilukuri and Ranka, "*Elements Of Artificial Neural Networks*", Penram International, 1st Ed., 1997
3. Rajasekaran, "*Neural Networks, Fuzzy Logic And Genetic Algorithm"*, PHI, 1st Ed., 2007
4. Principe Jose, "*Neural And Adaptive System*", John Wiley, Har / Cdr Ed., 2000
5. Gupta, Liang and Homma, *"Static And Dynamic Neural Networks",* John Wiley & Sons, E-Book, 2005
Electronics

B.TECH. III (ELECTRICAL), SEMESTER – VI

EE 302 : MICROCONTROLLERS AND EMBEDDED SYSTEMS

- **REVIEW OF 8051 ARCHITECTURE (05 Hours)**

  General purpose registers, on-chip RAM, timers-counters, special function registers, 8051 interrupt system, input/output ports and circuits

- **ADDITIONAL FEATURES OF 8051 ARCHITECTURE (08 Hours)**

  UART, concept of SPI & I2C serial interface, programmable counter array (PCA), PWM signal generation, watchdog timers.

- **INTRODUCTION TO EMBEDDED 'C' PROGRAMMING (05 Hours)**

  Variables and constants, storage classes, enumerations and definitions, I/O operations, control statements, functions, pointers and arrays, structure and unions, interrupt service routines.

- **INTERFACING AND PROGRAMMING OF 8051 WITH EXTERNAL HARDWARE (07 Hours)**

  External memory, ADC and DAC, matrix keyboard, LCD, 7 segment display.

- **INTRODUCTION TO 32-BIT TO ARM PROCESSOR ARCHITECTURE (05 Hours)**

  32-Bit Arm 7 and Cortex M-3 core, Harvard and Von-Neuman Architecture, AHB and Bus Matrix, Register Structure

- **INTRODUCTION TO EMBEDDED SYSTEMS (03 Hours)**

  Embedded systems description, definition, design considerations & requirements, embedded processor selection & tradeoffs, embedded design life cycle, product specifications, hardware/software partitioning, Co-Design concept..

- **EMBEDDED SOFTWARE ARCHITECTURE (06 Hours)**

  Concept of real time systems, concept of real-time task scheduling, scheduling methods, and introduction to real time operating systems (RTOS).

- **APPLICATIONS OF EMBEDDED SYSTEMS (05 Hours)**

  Measurement of analog and electrical variables, control of electrical devices, user interface in embedded systems, data communication in embedded systems.

Total Hours:43

LIST OF EXPERIMENTS:

1 Timer driven clock
2 Study of External Hardware Interrupts
3 Measurement of frequency of External waveform
4 Parallel A/D & D/A Converter
5 Study of high speed A/D Converter
6 Study of Synchronous Serial Protocol (I^2C & SPI)
7 Interfacing of Stepper Motor
8 Interfacing of PMDC Motor
9 Firing of Traic
10 Measurement of Electrical Quantity.
11 A Synchronous Serial Communication (UART)

REFERENCES:

1. Kenneth J. Ayala, "The 8051 Microcontroller", Penram International 3rd edition
2. M. Mazidi and others, "The 8051 Microcontroller and Embedded Systems", PRENTICE Hall Of India, 3rd Edition
3. David Seal, "ARM Architecture Reference Manual"
4. Trevor Martin, "The Insider's Guide To The Philips ARM7-Based Microcontrollers", Published by Hitex (UK) Ltd., April 2005.
5. Barnett & others, "Embedded C Programming and Microchip PIC", Thomson Learning Inc. , 1st Edition
6. David E. Simon, "An Embedded Software Primer" , Addision Wesley Pearson Education, 1999.

EE 304 : POWER SYSTEMS ANALYSIS

- **REPRESENTATION OF POWER SYSTEM COMPONENTS** **(04 Hours)**

  Introduction, single phase solution of balanced three phase networks, the one line diagram and the impedance or reactance diagram, per-unit (pu) system, complex power, synchronous machine, representation of loads.

- **REVIEW OF SYMMETRICAL COMPONENTS AND ITS APPLICATION TO POWER SYSTEM** **(05 Hours)**

  Symmetrical component transformation, phase shift in star-delta transformers, sequence impedance of transmission lines, sequence impedance and sequence network of power system, sequence impedance and network of synchronous machine, sequence impedance of transmission lines, sequence impedance and networks of transformers, construction of sequence networks of power systems.

- **SYMMETRICAL FAULT ANALYSIS** **(05 Hours)**

  Introduction, transient on a transmission line, short circuit of a synchronous machine on no load, short circuit of a loaded synchronous machine, balanced three phase fault, short circuit capacity, fault analysis using bus impedance matrix, selection of protective equipments.

- **UNSYMMETRICAL FAULT ANALYSIS** **(08 Hours)**

  Symmetrical component analysis of unsymmetrical faults, single line to ground (LG) fault, line to line (LL) fault, double line to ground (LLG) fault, open conductor faults, bus impedance matrix method for analysis of unsymmetrical faults.

- **POWER SYSTEM STABILITY** **(08 Hours)**

  Introduction, dynamics of a synchronous machine, power angle equation, power angle curve, simple systems, steady state stability, transient stability, equal area criteria, numerical solution of swing equation, some factors affecting transient stability.

- **POWER SYSTEM TRANSIENTS** **(06 Hours)**

  Types of system transients, factors affecting transients, reflection and refraction of traveling waves at different line termination, surge impedance, transient over voltages due to lightning, theory of ground wires, direct stroke to a tower, capacitive switching, kilometric fault, ferro-resonance, protection of power systems against transients and insulation coordination

- **INTRODUCTION TO HVDC AND FACTS** **(06 Hours)**

  Kinds of HVDC links, Asynchronous and synchronous links, limitations and advantages of HVDC links, converters, Basics of FACTS controllers and different configurations.

Total Hours:42

LIST OF EXPERIMENTS:

Simulations based on different types of faults, stability and transients using MATLAB and ETAP.

REFERENCES:

1. G.W. Stagg & A. H. EI-Abaid, “Computer methods in Power System Analysis”, McGraw Hill, New York.
2. W. D. Stevenson , “Element of Power System Analysis”, Mc Graw Hill, 1982.
3. Nagrath & kothari, “ Power System Engineering”, TMH publishing Company Ltd.
4. C.L.Wadhwa, “Electric Power System”, New Age International Ltd.
5. C. S. Indulkar and D P Kothari, “Power System Transients, A Statistical Approach”, Prentice Hall of India Pvt Ltd., New Delhi.
6. N. G. Hingorani, J Gyugi, “Understanding FACTS”, IEEE Press.
7. K. Bhattacharya, MHT Bollern and J. C. Doolder, “Operation of Restructured Power Systems”, Kluwer Academic Publishers, USA, 2001.

EE 306 : POWER ELECTRONIC CONVERTERS

- **INTRODUCTION** **(06 Hours)**

  Power Electronics Scope and Applications, Interdisciplinary Nature of Power Electronics, Types of power electronics circuits, Thyristor Characteristics, Two transistor analogy, Gate Characteristics, Methods of triggering and commutation, Ratings and protection of devices, Introduction to power electronic devices like Power BJT, MOSFET, GTO, IGBT, MCT etc.

- **PHASE CONTROLLED RECTIFIERS** **(12 Hours)**

  Principle of phase control, half wave controlled rectifiers, half wave controlled rectifiers with R, R-L, R-L-E load, single phase full wave controlled converters, 2-pulse mid-point converters, 2-pulse half and fully controlled bridge converters with R, R-L, R-L-E load, Three phase converter system with diodes, 3 phase half and fully controlled bridge converters, triggering scheme, Effect of source impedance on the performance or the converters, Dual converters.

- **CHOPPERS** **(08 Hours)**

  Basic principle of chopper operation, Control strategies – Duty Ration Control and Frequency Control, Types of idealized chopper circuits, Steady state time domain analysis of Type A choppers, Step up chopper.

- **INVERTERS** **(10 Hours)**

  Forced commutated inverters, Single phase voltage source inverters, Half bridge inverters, full bridge inverters, Steady state analysis, Voltage control in single phase inverters, 3-phase bridge inverters, Pulse width modulated inverters, Reduction of harmonics in Inverter.

- **AC VOLTAGE CONTROLLERS** **(08 Hours)**

  Principle of AC Voltage Controllers – Integral Cycle Control and Phase Control, Types of AC voltage controllers, Analysis of 1-phase Integral Cycle Control AC controllers with R load, Analysis of 1-phase Phase Control AC controllers with R and R-L load.

Total Hours: 44

LIST OF EXPERIMENTS:

1. Study Of Igbt, Mosfet, Scr, Triac, Diac Characteristics.
2. Study Of Different Scr Triggering Circuit Trainer – Dc, R, R-C, Ujt.
3. Study Of Single Phase Half Controlled Bridge Converter With R, R-L Load.
4. Study Of Single Phase Fully Controlled Bridge Converter With R, R-L Load.
5. Study Of Single Phase Scr Full Bridge Inverter Circuit.
6. Study Of High Voltage Thyristorised Chopper
7. Study Of Single Phase Ac Voltage Controller Using Scr.
8. Study Of Single Phase Ac Voltage Controller Using Triac.
9. Study Of Single Phase Dual Converter Circuit.
10. Study Of Scr Dc Circuit Breaker Circuit.
11. Study Of Three Phase Scr Triggering Circuit Using Tca785 Ic.
12. Study Of Ac Solid State Relay Using Ic 555, Opto Coupler & Triac.
13. Simulation Of Power Ec CIRCUITS IN PSIM AND SIMULINK.

REFERENCES:

1. Bimbhra, P. S., "Power electronics", Khanna Publishers, New Delhi, 2001.
2. Rasid, M. H., " Power Electronics Circuits, Devices, and Applications, Prentice-Hall of India Pvt. Ltd., New Delhi, 2nd edition, 1999.
3. Singh, M. D., Khanchandani, K. B., "Power electronics", Tata McGraw-Hill Publishing Co. Ltd., New Delhi, 2001.
4. Ned Mohan, Tore M. Undeland and William P. Robbins, “Power Electronics Converters, Applications, and Design”, John Willey & Sons, Inc., 2nd Edition, 1995.
5. Agrawal, J. P., "Power electronic systems: Theory and design" Addison Wesley Longman (Singapore) Pte. Ltd. New Delhi, 2001.

EE 308 : INSTRUMENTATION

- **PERFORMANCE AND CHARACTERISTIC OF MEASUREMENT SYSTEMS (06 Hours)**

  Elements of generalized measurement system, input-output configuration of instruments and measurement systems, methods of correction for interfering and modifying inputs, static performance characteristics of measurement system, noise, signal to noise ratio, errors in measurement

- **TRANSDUCERS (08 Hours)**

  Classification of transducers, passive transducers: resistive, inductive and capacitive transducers, active transducers: thermocouple, piezoelectric transducer, taco-generator, pH cell, basic signal conditioning circuits for transducers.

- **ELECTRONIC METERS AND OSCILLOSCOPE (07 Hours)**

  DC amplifier voltmeter, AC voltmeter using rectifiers, true RMS responding voltmeter, Hall effect wattmeter, Oscilloscope block diagram, CRT and its circuits, vertical deflection systems, delay line, multiple trace, horizontal deflection system, oscilloscope probes. Special Oscilloscopes: Sampling oscilloscope, storage oscilloscope

- **OPERATIONAL AMPLIFIER FUNDAMENTALS (04 Hours)**

  Operational Amplifier, Basic Op-Amp Configuration, An Op-Amp With Negative Feedback, Voltage Series And Voltage Shunt Configurations, Difference Am plifiers,
  Specification Of An Op-Amp, Offset Voltages And Currents, CMRR, Slew Rate

- **LINEAR APPLICATIONS OF OPERATIONAL AMPLIFIERS (06 Hours)**

  Summing, Scaling And Averaging Amplifiers, Voltage To Current Converter With Floating And Grounded Load, Current To Voltage Converter, Integra tor And Differentiator, Instrumentation Amplifier

- **NON-LINEAR APPLICATIONS OF OPERATIONAL AMPLIFIERS (06 Hours)**

  Schmitt Trigger, Voltage Comparator, Voltage Limiters And Window Detector, Clippers And Clampers, Peak Detector, Precision Rectifiers, Analog Switches

- **TEST INSTRUMENTATION (07 Hours)**

  High voltage oil testing equipment, H.V. breakdown tester and its applications, insulation tester and its applications, calibration and traceability of instruments: calibration of energy meter, oscilloscope, localization of cable faults: loop testing and time domain pulse echo technique.

Total Hours:44

LIST OF EXPERIMENTS:

1. Calibration of LVDT
2. Instrumentation Amplifier and Measurement of temperature using Thermocouple
3. Measurement of liquid level
4. LCR-Q Meter
5. Strain Gauge
6. High voltage oil Testing
7. CRO and Function generator
8. Localization of cable fault
9. Zero Crossing Detector
10. Inverting & Non-Inverting Amplifier
11. Summing, Scaling & Averaging Circuits
12 Integrator & Differentiator
13. Active Filters
14. Application of Timer IC 555
15. Voltage Regulator

REFERENCES:

1. A. K . Sawhney, “Electrical and electronic Measurements and Instrumentation”, Dhanpat Rai & co.,17th edtion
2. Gayakwad Ramakant, “Op-Amps And Linear Integrated Circuits” , PHI, 3rd Ed., 1993
3. Helfrick A D; Cooper W. D., “Modern electronic Instrumentation and Measurement techniques”, PHI ,Edition 1997
4. Rangan; Sarma; Mani, “Instrumentation devices and systems”,TMH, 2nd edition
5. Doebelin E.O, “Measurement Systems - Application and Design”, Fourth edition, McGraw-Hill, New York, 1992
6. Coughlin and Driscol, “Op-Amps And Linear Integrated Circuits”, PHI, 5th Ed., 1998

B.Tech. III, Semester – VI

EE 322: POWER SYSTEM PLANNING AND MANAGEMENT

- **FORECASTING-NEEDS & USES** **(11 Hours)**

  Current Status Of Forecasting, Fundamentals Of Quantitative Forecasting, Explanatory And Time Serious Forecasting, Least Square Estimates, Peak Load Forecasting, Accuracy Of Forecasting Methods, Regression Methods, Box Jenkins Time Serious Methods.

- **SHORT AND LONG TERM FORECASTING TECHNIQUES** **(11 Hours)**

  Problems facing electricity industry, Long term forecasting techniques, Methods of long term forecasting, Spatial load forecasting, Multivariate procedures, Short term forecasting techniques

- **FORECASTING AND PLANNING** **(10 Hours)**

  The role of forecasting in planning, Comparison and selection of forecasting methods, The accuracy of forecasting methods, Pattern of the Data and its effects on individual forecasting methods, Time horizon effects on forecasting methods.

- **GENERATION PLANNING** **(10 Hours)**

  Fundamental economic analysis, Generation planning optimized according to generating unit categories, distribution & Transmission system planning.

Total Hours:42

REFERENCES:

1. Makridakis, Spyros, “Forecasting methods and application”, John Wiley, 1993.
2. X.Wang & J.R. Mc Donald , “Modern Power system planning”, McGraw. Hill, 1993
3. A.S Pabla , “Electrical Power system planning”, Mac Millan,Delhi,1998
4. Sullivan, “Power system planning”, McGraw. Hill ,1977
5. Lakervi E, E J Holmes, “Electricity distribution network design”, IEE, 2nd edition, 2003

B. Tech
4^{th} year

B.TECH. IV (ELECTRICAL), SEMESTER – VII

EE 401 : ELECTRONIC INSTRUMENTATION

- **DIGITAL MEASUREMENT** **(07 Hours)**

  Digital measurement techniques for voltage, current, power, energy, resistance, capacitance and loss angle (TAN ∂), impedance and quality factor

- **DIGITAL FREQUENCY AND TIME MEASURING INSTRUMENTS** **(04 Hours)**

  Frequency counter, period duration meter, pulse width meter, frequency ratio meter, error in digital instruments

- **SENSORS** **(04 Hours)**

  Principle and applications of photosensitive, and fiber optic sensors

- **SIGNAL CONDITIONING, DATA ACQUISITION AND CONVERSION** **(09 Hours)**

  Instrumentation amplifiers, isolation techniques, sample and hold circuits, multiplexers and demultiplexers, digital to analog converters, data acquisition systems, encoders, grounding and shielding techniques.

- **AN OVERVIEW OF PLC** **(06 Hours)**

  Introduction, definitions and history of PLC, manufacturing and assembly processes, PLC advantages and disadvantages, overall PLC system, CPU, PLC, input and output modules, program recording devices

- **PROGRAMMING PLC** **(08 Hours)**

  Ladder diagrams, programming ON/OFF inputs to produce ON/OFF outputs, digital gate logic and contact coil logic, creating ladder diagrams from process control descriptions ,register, timer function, counter function, arithmetic functions, comparison functions

- **INTRODUCTION TO DISTRIBUTED CONTROL SYSTEM** **(04 Hours)**

  DCS architecture, communication protocol

Total Hours:42

REFERENCES:

1. Helfrick A D; Cooper W. D. , “Modern electronic Instrumentation and Measurement techniques”, PHI ,Edition 1997
2. Rangan; Sarma; Mani , “Instrumentation devices and systems”, TMH , 2nd edition
3. Doebelin E.O, “Measurement Systems - Application and Design”, Fourth edition, McGraw-Hill, New York, 1992.
4. T.S Rathore, “Digital Measurement Technique”, Narosa publishing house,2nd edition
5. Curtis Johnson, “Process control instrumentation technology”, PHI, 6th edition
6. John. W .Webb Ronald A Reis , “Programmable Logic Controllers - Principles and Applications”, Fourth edition, Prentice Hall Inc., New Jersey, 1998.

B.Tech. IV (Electrical), Semester – VII

EE 403 : ELECTRICAL DRIVES

- **FUNDAMENTALS OF ELECTRIC DRIVES** **(03 Hours)**

  Electrical drives and introduction: Electric drives, advantages of electrical drives, parts of electrical drives, choice of electrical drives, status of ac and dc drives. types of load, load with translational motion, load with rotational motion, load torque that vary with time, Speed Sensing , and current Sensing

- **DYNAMICS OF ELECTRICAL DRIVES** **(04 Hours)**

  Fundamental torque equation, speed-torque convention and multi quadrant operation, , dynamics of motor load combination, nature and classification of load torque, measurement of moment of inertia, calculation of acceleration time in transient operation, acceleration time for specific nature of motor and load torque, load equalization, stability of electrical drives. Selection of Motor Power Rating,

- **POWER ELECTRONICS CONTROL OF DC DRIVES** **(05 Hours)**

  Review of DC Motors and its performance, starting, braking, controlled rectifier fed DC drives with continuous and discontinuous mode of operation, Supply Harmonics, Power Factor and ripple in motor current, Chopper Controlled DC Drives, Sources current harmonics in chopper, Converter Ratings and closed loop control.

- **POWER ELECTRONICS CONTROL OF AC DRIVES** **(13 Hours)**

  Review of Three phase Induction Motor and its performance, starting, braking, Static Voltage control , Variable Frequency Control (VSI, CSI, Cyclo-converter based), static rotor resistance control and slip power recovery control schemes.

- **THREE PHASE SYNCHRONOUS MOTORS** **(12 Hours)**

  Review of Three phase Synchronous Motor and its performance, Self controlled schemes, Variable frequency control of multiple synchronous motor, Permanent magnet AC motor drives, Brushless DC Motor Drives

- **INDUSTRIAL APPLICATIONS** **(05 Hours)**

Total Hours:42

LIST OF EXPERIMENTS:

1. Study Of Speed Control Of Dc Shunt Motor Using Single Phase Fully Controlled Converter.
2. Controlling Of Dc Motor With Single Phase Dual Converter.
3. Study Of Speed Control Of (V/F Control) Of Single Phase Induction Motor.
4. Study Of Speed Control Of (V/F Control) Of Three Phase Ac Induction Motor.
5. Study Of Ac Servo Motor Position Control Trainer.
6. Study Of Hitachi Makes 5 Hp Induction Motor Drives.
7. Study Of Dsp Controlled Induction Motor Drive.
8. Study Of Dsp Controlled Bldc Motor Drives.

REFERENCES:

1. Dubey G.K, “Fundamentals of Electrical Drives”, Narosa Publishing House, Second Edition, 2001.
2. Pillai S.K., “A First Course on Electrical Drives”, New Age International , Second Edition, 2006.
3. De N.K., Sen P.K. “Electric Drives”, Prentice Hall of India, Second Edition , 2001.
4. Krishnan, R, “Electric Motor Drives: Modeling, Analysis and Control ” ,Prentice Hall of India, Second Edition , 2001.
5. Ned Mohan et al, “Power Electronics: Converters, Applications, and Design”, John Wiley & Sons. Inc., 2nd Edition, 1995.
6. Werner Leonhard, “Control of electrical drives”, Springer, 1995.

EE 405 : SWITCHGEAR & PROTECTION

- **FUSES, SWITHCHES AND NEUTRAL GROUNDING** **(03 Hours)**

  Rewirable fuses, HRC fuses, isolators and earthing switches, selection of fuses. Effectively grounded and ungrounded systems, resonant grounding Methods of neutral grounding.

- **BASIC PRINCIPLES AND RATINGS OF CIRCUIT BREAKERS** **(05 Hours)**

  Arc phenomenon, arc Interruption theories, arc control devices, recovery and restriking voltages, current chopping, Interruption of capacitive current, resistance switching, circuit breaker operating mechanism and control systems, making current, breaking current symmetrical and unsymmetrical, continuous current rating, MVA capacity.

- **CIRCUIT BREAKERS** **(06 Hours)**

  Bulk oil circuit breaker, arc controlled devices, MOCB, ACB, ABCB, SF_6 circuit breaker, vacuum circuit breaker and DC circuit breakers, circuit breaker ratings, autoreclouser. Testing of circuit Breaker.

- **FUNCTIONS OF PROTECTIVE RELAYING** **(03 Hours)**

  Fundamental characteristics of relays, standard definition of relay terminologies, relay classifications, operating principles of single and double actuating quantity type electromechanical relays, directional relay, reverse power relay.

- **GENERATOR & MOTOR PROTECTION** **(04 Hours)**

  Modern methods of protecting generators against faults in stator, rotor and prime movers and other abnormal conditions. Abnormal operating conditions, under voltage, phase and earth fault, overload and unbalanced voltage protections for motors.

- **TRANSFORMER PROTECTION** **(04 Hours)**

  Protection of transformers, basic differential over current relays, restricted earth fault protection, gas relays, overall generator-transformer differential protection, magnetizing inrush protection.

- **BUSBAR PROTECTION** **(03 Hours)**

  Protection of out door and indoor busbar by current differential, voltage differential and directional comparison principles, linear coupler, high impedance schemes.

- **TRANSMISSION LINE PROTECTION** **(07 Hours)**

  Operating characteristics of impedance, reactance relays on R-X diagram, overreach and memory action, ohm and mho types relays and their characteristics, relay response under power swings and effect of fault resistance, setting of distance relays.
  Carrier Current Protection- Phase comparison and directional comparison principles.

- **SOLID STATE RELAYS** **(04 Hours)**

  Phase and amplitude comparators, duality between phase and amplitude comparators, general equation for comparators, realization of directional, ohm, reactance, impedance and mho characteristics using general characteristic equation, qualitative concepts of switched and non-switched scheme of static distance relays.

- **INTRODUCTION TO COMPUTER AIDED RELAYING** **(03 Hours)**

  Introduction to microcomputer based relays, general functional diagram of microcomputer based relays.

Total Hours:42

(Continued…)

LIST OF EXPERIMENTS:

1. To obtain the operating characteristics of an instantaneous overcurrent relay.
2. To obtain the operating characteristics of an inverse time overcurrent / overvoltage relay.
3. To study the operating characteristics of directional overcurrent relay.
4. To study the operating characteristics of the transformer percentage differential relay.
5. To study the transient in the s/c applied at the terminals of synchronous machine.
6. To study the magnetic inrush current in a transformer.

REFERENCES:

1. M. A. Date, B.Oza, N.C. Nair, “Power System Protection”, Bharti Prakashan,2004
2. J. Lewis Blackburn, “Protective Relaying”, Marcel Dekker INC. 1997
3. Russel Mason, “Art and Science of Protection relaying”
4. Allen Greenwood, “Electrical Transients in Power Systems”, 1991.
5. Van. C. Warrington A.R., “Protective Relays Vol. 1 & 2”, Chapman & Hall, 1998.
6. T S Madhav Rao, “Power system protection static relays with microprocessor Applications”, Tata McGraw hill Publication,1998.
7. Badri Ram, D N Vishwakarma, “Power System Protection and Switchgear”, Tata Mc Graw Hill, 2005.
8. Anderson P M, “Power System Protection”, IEEE publication, 1999.
9. Walter -Marcel Dekker, “Protective relaying theory and applications”, 2ed, Elmore, 2004.

B.Tech. IV (Electrical) Semester-VII

EE 417 : DISCRETE CONTROL SYSTEM

- **INTRODUCTION TO DISCRETE-TIME CONTROL SYSTEMS** **(03 Hours)**

  Introduction, digital control systems, quantizing and quantization error, data acquisition, conversion, and distribution systems.

- **THE Z TRANSFORMATION** **(08 Hours)**

  The z transform, transforms of elementary functions, important properties and theorems of the z transform, the inverse z transform, z transform method for solving difference equations.

- **Z-PLANE ANALYSIS OF DISCRETE-TIME CONTROL SYSTEMS** **(08 Hours)**

  Impulse sampling and data hold, obtaining the z transform by the convolution integral method, reconstructing original signals from sampled signals, the pulse transfer function, realization of digital controllers and digital filters.

- **DESIGN OF DISCRETE-TIME CONTROL SYSTEMS** **(10 Hours)**

  Introduction, mapping between the S plane and the z plane, stability analysis of closed-loop systems in the z plane, transient and steady-state response analysis, design based on the root-locus method, design based on the frequency-response method, analytical design method.

- **STATE-SPACE ANALYSIS** **(08 Hours)**

  State-space representations of discrete-time systems, solving discrete-time state-space equations, pulse-transfer-function matrix, discretization of continuous-time state-space equations, liapunov stability analysis.

- **POLE PLACEMENT AND OBSERVER DESIGN** **(05 Hours)**

  Controllability, observability, useful transformations in state-space analysis and design, via pole placement, state observers, servo systems.

Total Hours:42

REFERENCES:

1. K.Ogata, “Discrete time control system”, Pearson Education ,Inc.
2. Kuo, B.C., “Discrete data control system”, Prentice-Hall.
3. Nagrath & Gopal, “Control system engineering” New Age International Publishers, 3rd Edition, 2001.
4. M.Gopal, “Digital control System”.
5. B.C.Kuo, “Automatic control system”, Prentice Hall of India, 7th Edition, 1995.

B.TECH. IV (ELECTRICAL), SEMESTER – VIII

EE 402 : POWER SYSTEM OPERATION AND CONTROL

- **LOAD FLOW STUDIES** **(07 Hours)**

  Network model formulation, formation of Y bus, power flow problem, different types of buses, approximate power flow, Gauss Seidel method, Newton-Raphson method, Decoupled Power flow studies, Fast Decoupled power flow studies, comparison of power flow methods.

- **ECONOMIC LOAD DISPATCH** **(05 Hours)**

  Economic dispatch of thermal units and methods of solution, Transmission losses, B matrix loss formula, Composite generation production cost function-solution by gradient search techniques, Nonlinear function optimization

- **AUTOMATIC GENERATION CONTROL** **(05 Hours)**

  Single area load frequency control, speed governing system and characteristics, Multiarea load frequency control; flat frequency, flat tie-line load and tie-line load bias control, Economic Dispatch and AGC, EMS, SCADA

- **METHODS OF VOLTAGE CONTROL** **(04 Hours)**

  Reactive power and its relation to voltage control, location of voltage control equipment, methods of voltage control, excitation control, voltage regulators, tap changing transformers, booster transformers, induction regulators, reactive power injection and voltage control by synchronous condenser

- **UNIT COMMITMENT** **(05 Hours)**

  Constraints in Unit commitment, Spinning reserve, Thermal and hydro constraints, Unit commitment solution methods- Priority list methods, Dynamic programming solution

- **HYDRO THERMAL SCHEDULING** **(06 Hours)**

  Short and long range hydro-thermal scheduling, hydroelectric plant models, scheduling problems, Short range hydro-thermal scheduling: Gradient approach, Pumped storage hydro plants, Dynamic programming solution to the hydrothermal scheduling problems

- **POWER SYSTEM SECURITY** **(06 Hours)**

  Factors affecting power system security, Contingency analysis: Detection of network problems, Correcting the generation approach: Sensitivity methods, compensated factors, correcting the generation dispatch using linear programming

- **STATE ESTIMATION IN POWER SYSTEMS** **(04 Hours)**

  Power system state estimation, least square estimation, state estimation of an AC network, Detection and identification of bad measurements

Total Hours:42

REFERENCES:

1. A. J. Wood and B.F. Wollenberg, “Power Generation Operation and Control”, John Wiley & Sons, ICN., 2nd Edition.
2. A. K.Mahalanabis, “Computer Aided Power system analysis and control”, Tata McGraw Hill 1991
3. O. I. Elgerd, “Electric Energy Systems Theory”, McGraw Hill, 2nd Edition, 1982,Dec
4. Stevenson J V, William D, “Elements of Power System Analysis”, McGraw Hill, 1988.
5. I. J. Nagrath & D.P. Kothari, “Modern Power System Analysis”, Tata McGraw Hill,1989
6. Arthur R Bergen, Vijay Vittal, “Power system Analysis”, Pearson Education (Singapore) Pte, Ltd., 2004
7. Hadi Saadat, “Power System Analysis”, Tata Mc Graw Hill, 2003.
8. J Arrilaga, C P Arnold, B J Harker, “Computer Modelling of Electric Power Systems”.
9. Elgerd olleI, “Electric Energy Sytems Theory- An Introduction”, Tata Mc Graw Hill, 2ed. 1995.
10. Wadhwa C L, “Electrical Power Systems”, New Age Publication, 3ed., 2002

B.Tech. IV (Electrical), Semester-VIII

EE 404 : ELECTRICAL MACHINE DESIGN

- **TRANSFORMERS** **(10 Hours)**

  Output equation - single phase and three phase power transformers - main dimensions - choice of specific electric and magnetic loadings- design of core, LV winding, HV winding, tank and cooling tubes - prediction of no load current, forces on winding during short circuit, leakage reactance and equivalent circuit based on design data - design examples.

- **DC MACHINES** **(11 Hours)**

  Output equation - main dimensions - choice of specific electric and magnetic loadings - choice of speed and number of poles - design of armature conductors, slots and winding - design of air-gap, field system, commutator, interpoles, compensating winding and brushes – Carter's coefficient - real and apparent flux density - design examples.

- **ALTERNATORS** **(10 hours)**

  Output equation - salient pole and turbo alternators - main dimensions - choice of specific electric and magnetic loadings - choice of speed and number of poles - design of armature conductors, slots and winding - design of air-gap, field system and damper winding - prediction of open circuit characteristics and regulation of the alternator based on design data - design examples.

- **INDUCTION MACHINES** **(11 Hours)**

  Output equation - main dimensions - choice of specific electric and magnetic loadings - design of stator and rotor windings, stator and rotor slots and air-gap of slip ring and squirrel cage motors – calculation of rotor bar and end ring currents in cage rotor - calculation of equivalent circuit parameters and prediction of magnetising current based on design data - design examples.

Total Hours:42

REFERENCES:

1. Clayton & Hancock, "Performance & Design Of DC Machines", CBS, 3rd edition, 2001
2. Sawhney, Chakrabarti, "A Course in Electrical Machine Design", Dhanpat Rai & Co., 2006.
3. Say M. G, "Performance & Design of AC Machines", Pitman, ELBS.3rd edition, 1983.
4. S.K.Sen, "Principles of Electrical Machine Design", Oxford & IBH Pub., 2006
5. R. K. Agarwal, "Principles of Electrical Machine Design", S. K. Kataria & Co., 2005.

B. Tech. IV (Electrical), Semester – VIII

EE 406 : ADVANCED POWER ELECTRONIC CONVERTERS & APPLICATIONS

- **MODERN SEMICONDUCTOR DEVICES** **(04 Hours)**

  Power Diodes, Power BJT, Power MOSFETs, Thyristor, GTOs, IGBT, MCT – Basic characteristics and controlling, Emerging devices and circuits, Power Integrated Circuits.

- **PRACTICAL DESIGN CONSIDERATION** **(06 Hours)**

  Gate and Base drive circuits – Design Consideration for different Devices, DC-Coupled Circuits, Isolated Drive Circuits, and Protection in Drive Circuits. Snubber circuits Designing, Temperature control and Heat sink design consideration, Design of Magnetic Components.

- **DC-DC SWITCHED MODE CONVERTERS** **(08 Hours)**

  Introduction, Step-Down (Buck) Converter, Step-Up (Boost) Converter, Buck-Boost Converter, C uk Converter, Control Principles, Applications of DC-DC Converters.

- **SWITCHING DC POWER SUPPLIES** **(08 Hours)**

  Introduction, Linear Power Supplies, Switching Power Supplies, DC-DC Converter with isolation - Flyback converters, Half Bridge Converters, Full Bridge converters, Forward Converter, Push-pull converter, Protection, Isolation and Design criteria for SMPS.

- **STATIC POWER ELECTRONICS APPLICATIONS** **(06 Hours)**

  Electronic Ballasts, UPSs, Power Electronics in Capacitor Charging Applications, Power Electronics for Renewable Energy Sources HVDC Transmission, Automotive Applications of Power Electronics.

- **POWER ELECTRONICS IN POWER QUALITY** **(05 Hours)**

  Power Quality, Reactive Power and Harmonic Compensation, IEEE Standards, Static VAR Compensator, Thyristor Controlled Reactor (TCR), Thyristor Switched Capacitors (TSC), Principal of Active Filters, Types of Active Power Filters, Shunt Active Power Filters, Series Active Power Filters.

- **COMPUTER SIMULATION OF POWER ELECTRONICS AND CONTROL METHODS** **(05 Hours)**

  Introduction, Use of Simulation Tools for Design and Analysis, Simulation of Power Electronics Circuits with PSpice, PSIM, Matlab-Simulink, Control Methods for Power Converters like Power Converter Control using State-Space Averaged Models, Sliding Mode Control of Power, Fuzzy Logic Control of Power.

Total Hours:42

REFERENCES:

1. Rashid, M. H., “Power Electronics Handbook”, Elsevier Academic Press, 2001
2. Ned Mohan, Tore M. Undeland and William P. Robbins, “Power Electronics Converters, Applications, and Design”, John Willey & Sons, Inc., 2nd Edition, 1995.
3. Agrawal, J. P., “Power electronic systems: Theory and design”, Addison Wesley Longman (Singapore) Pte. Ltd. New Delhi, 2001.
4. Rashid, M. H., “Introduction to PSpice Using OrCAD for Circuits and Electronics”, Prentice-Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, Third Edition 2006.
5. Singh, M. D., Khanchandani, K. B., “Power electronics”, Tata McGraw-Hill Publishing Co. Ltd., New Delhi, 2001

B.Tech. IV (Electrical), Semester – VIII

EE 424 : NON LINEAR AND OPTIMAL CONTROL SYSTEMS

- **INTRODUCTION TO NONLINEARITY: (04 Hours)**

  Introduction to nonlinear components and systems, inherent and intentional nonlinearity, specific example of non linear spring for introducing non linearity like jump resonance and variation of resonant frequency with amplitude of input.

- **DESCRIBING FUNCTION ANALYSIS OF NONLINEAR CONTROL SYSTEM: (08 Hours)**

  Introduction to Nonlinear Systems Describing Functions for Common Types of Nonlinearities Describing Function Analysis, Stability and Limit Cycles.

- **PHASE-PLANE ANALYSIS: (14Hours)**

  Introduction, Analytical Methods for constructing Trajectories, Graphical Methods for constructing Trajectories, Isocline Method, Delta Method, Pell's Method, Lienard's Method, Classification of Singular Points, Limit Cycles, Phase-Plane Analysis of Linear control systems, Phase-Plane Analysis of' Non-linear control systems, Minimum Time Trajectory, Optimum Switching Curve.

- **OPTIMAL CONTROL SYSTEM: (16 Hours)**

  Introduction, Calculus of Variation Fixed-End-Point Problem, Free-End-Point Problem and constrained variation problem, Optimal Control Problems, The Hamiltonian Formulation, A Linear Regulator Problem, Pontryagin's Minimum Principle, Minimum Time problems, Fuel optimal problem.

Total Hours: 42

REFERENCES:

1. Nagrath & Gopal, “Control system engineering”, New Age International Publishers, 3rd Edition, 2001.
2. K. Oggata, “Modern control system engineering”, Pearson Education Asia, 4th Edition, 2002.
3. B.C.Kuo, “Automatic control system”, Prentice Hall of India, 7th Edition, 1995.
4. Richard C Dorf & Robert H Bishop, “Modern control system”, Pearson Education Asia. 8th Edition, 2004.
5. Nise N. S., “Control System Engineering”, John willey & sons, 4th Edition, 2004