Approved Syllabus for

Master of Technology

in

CONTROL SYSTEMS

From Academic Year 2015 - 2016

in

SECOND BOARD OF STUDIES MEETING HELD

on

April 25th & 26th , 2015

DEPARTMENT OF ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING *(AUTONOMOUS), ANANTHAPURAMU*

JAWHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR

INFORMATION ON THE COURSE

1.1 Name of the Course

Name of Degree / Diploma	Name of Specialization	Intake (Full / Part time)	Year of Starting	Duration (Total)	Name of Degree & Branch eligible for admission
M. Tech.	Control Systems	25+7 Sponsored Full time	2009 – 10	2 Yrs/ 4 Semesters	4 Year Degree Course B. Tech./B.E. (EEE/EIE/ECE/ICE/EConE)

1.2 Course Structure and scheme of evaluation (Semester – wise)

Name of the Subject	Hrs. / Week			
	L	T	P	C
I – SEMESTER				
1. 15D22101 Modern Control Theory	4	-	-	4
2. 15D22102 Advanced Digital Signal Processing	4	-	-	4
3. 15D22103 Non - Linear Control Theory	4	-	-	4
4. 15D22104 Optimal Control	4	-	-	4
5. Elective - I	4	-	-	4
6. Elective - II	4	-	-	4
7. 15D22108 Control Systems Lab	-		4	2
Electives:				
1. 15D22105 PLC & Automation				
2. 15D22106 Robust Control				
3. 15D23103 Machine Modeling and Analysis				
4. 15D22107 Embedded Systems				
II – SEMESTER				
1. 15D22201 Adaptive Control	4	-	-	4
2. 15D22202 Digital Control Systems	4	-	-	4
3. 15D22203 Intelligent Algorithms	4	-	-	4
4. 15D22204 Estimation of Signals and Systems	4	-	-	4
5. Elective - III	4	-	-	4
6. Elective – IV	4	-	-	4
7. 15D54201 Research Methodology (Audit Course)	2	-	-	0
8. 15D22207 Control System Simulation Lab	-	-	4	2
Electives:				
1. 15D22205 Real Time Systems				
2. 15D21207 Solar Energy Conversion Systems				
3. 15D21208 Wind Energy Conversion Systems				
4. 15D22206 Process Dynamics and Control				
III SEMESTER				
1. 15D22301 Seminar - I	-	-	4	2
IV SEMESTER				
1. 15D22401 Seminar – II	-	-	4	2
III & IV SEMESTER				
1. 15D22302 Project Work	-	-	-	44

15D22101 MODERN CONTROL THEORY

Unit I

Fields, Vectors, and vector spaces; State space representation, state equations for dynamic systems, solution of state equations; State transition matrix – Properties of state transition matrix; evaluation. Fadeeva algorithm for conversion from state space to transfer function, Linearization of non-linear models

Unit II

Non uniqueness of state model, Similarity transformation, Invariance of system properties. Controllability – necessary and sufficient condition - Pole assignment using State feedback – Ackerman's formula for feedback gain determination; Observability. Duality. Effect of state feedback on controllability and observability. Controllable subspace – decomposition of state into controllable and uncontrollable components.

Unit III

Design of full order observer – Bass Gura algorithm. The separation principle - Combined observer – controller compensator. Design of reduced order observer. Unobservable subspace – decomposition of state into observable and unobservable components – Canonical decomposition theorem.

Unit IV

Reducibility – realization of transfer function matrices. Model decomposition and decoupling by state feedback. Design of robust control system for asymptotic tracking and disturbance rejection using State variable equations. Transfer function interpretations – transfer function form of observer and state estimate feedback. State space interpretation of internal model principle.

Unit V

Discrete time linear state regulator – Algorithm for the solution, Use of observer in implementing the control law. Continuous time linear state regulator – Matrix Riccati equation. Time invariant linear state regulator – the reduced matrix Riccati equation - An iterative method to solve the reduced matrix Riccati equation. Suboptimal linear regulator.

Text Books:

1. Modern Control Engineering, Katsuhiko Ogata, 5th Edition, Prentice Hall India, 1997
2. Modern Control System Theory, M. Gopal, Revised 2nd Edition, New Age International Publishers, 2005.

References:

1. Linear Systems, Thomas Kailath, Perntice Hall, 1980.
2. Control System Design, Graham C. Goodwin, StefanF. Graebe and Mario E. Salgado, Pearson Education, 2000.
3. Linear System Theory and Design, Chi-Tsong Chen, OXFORD University Press.
4. Richard C. Dorf and Robert H. Bishop, Modern Control Systems, 11th Edition, Pearson Edu India, 2009.

15D22102 ADVANCED DIGITAL SIGNAL PROCESSING

UNIT-I:
Short introduction, Analog to digital and Digital to Analog conversion, sampled and Hold circuit, Continuous time Fourier Transforms. Discrete-time signals and systems, Discrete-time Fourier transform- its properties and applications, Fast Fourier Transform (in time-domain and Frequency domain) , IDFT and its properties.

UNIT-II: z- Transforms
Definition and properties, Rational z-transforms, Region of convergence of a rational z- Transform, The inverse z- Transform, Z-Transform properties, Computation of the convolution sum of finite-length sequences, The transfer function.

Digital Filter Structures: Block Diagram representation, Equivalent structures, Basic FIR Digital Filter structures, Basic IIR Digital Filter structures, Realization of Basic structures using MATLAB, All pass filters, Computational complexity of Digital filter structures.

UNIT III: **IIR Digital Filter Design:**
Preliminary considerations, Bilinear transformation method of IIR Filter design, Design of low pass IIR Digital filters, Design of High pass, Band pass and band stop IIR digital filters, Spectral Transformations of IIR filter, IIR digital filter design using MATLAB, Computer aided design of IIR digital filters.

UNIT IV:FIR Digital Filter Design:
Preliminary considerations, FIR filter design based on windowed Fourier series, Computer aided design of Equiripple Linear phase FIR filters, Design of Minimum phase FIR filters, FIR digital filter design using MATLAB, Design of computationally efficient FIR digital filters.

UNIT V: Analysis of Finite word length effects:
The quantization process and errors, quantization of Fixed point numbers, Quantization of floating point numbers, Analysis of coefficient quantization effects, Analysis of arithmetic round off errors, Low sensitivity digital filters, Reduction of product round off errors using error feedback, Round off errors in FFT algorithms. The basic sample rate alteration devices, Multi rate structures for sampling rate conversion, Multistage design of decimator and interpolator, The Polyphase decomposition, Arbitrary-rate sampling rate converter, Nyquist Filters and some applications of digital signal processing.

Text Books:

1. S.K. Mitra**, Digital Signal Processing-**, Tata McGraw-Hill, Third Edition, 2006.
2. B.P. Lathi, **Principle of Signal Processing and Linear Systems-**, Oxford International Student Version, 2009
3. M. Mondal and A Asif, **Continuous and Discrete Time Signals and Systems**, Cambridge, 2007

References:

1. Li Tan, **Digital Signal Processing- Fundamentals and Applications-**, Indian reprint, Elsevier, 2008.
2. Alan V. Oppenheim, Ronald W. Schafer, and John R.Buck, **Discrete- Time Signal Processing-**, Pearson Edu, 2008.

15D22103 NONLINEAR CONTROL THEORY

UNIT I:

Linear versus nonlinear systems - Describing function analysis: Fundamentals, common nonlinearities (saturation, dead - zone, on - off non - linearity, backlash, hysteresis) and their describing functions.

UNIT II:

Describing function analysis of nonlinear systems. Reliability of describing method analysis. Compensation and design of nonlinear system using describing function method. Phase plane analysis: Phase portraits, Singular points characterization. Analysis of non - linear systems using phase plane technique. Existence of limit cycles. Linearization: Exact linearization, input - state linearization, input - output linearization.

UNIT III:

Concept of stability, Zero - input and BIBO stability, stability in the sense of Lyapunov and absolute stability, Stability in the small and stability in the large, Lyapunov stability definitions, First method of Lyapunov,. Second (or direct) method of Lyapunov stability theory for continuous and discrete time systems, Aids to generate Lyapunov function – Krasovskii's theorem, Variable gradient method.

UNIT IV:

Aizerman's and Kalman's conjecture. Construction of Lyapunov function - Methods of Aizerman, Zubov, Variable gradient method. Lure problem. Popov's stability criterion, generalized circle criterion, Kalman - Yakubovich - Popov Lemma. Popov's hyperstability theorem.

UNIT V:

Concept of variable - structure controller and sliding control, reaching condition and reaching mode, implementation of switching control laws. Reduction of chattering in sliding and steady state mode. Some design examples of nonlinear systems such as the ball and beam, flight control, magnetic levitation and robotic manipulator etc.

Text Books

1. J. E. Slotine and Weiping LI, Applied Nonlinear Control, Prentice Hall,
2. Hassan K. Khalil, Nonlinear Systems, Prentice Hall, 1996.

References:

1. Sankar Sastry, Nonlinear Systems Analysis, Stability and Control.
2. M. Vidyasagar, Nonlinear Systems Analysis, Prentice - Hall International editions,1993.

15D22104 OPTIMAL CONTROL

UNIT I

An overview of optimization problem - concepts and terms related to optimization - constrained and unconstrained problems and their solutions using different techniques.

UNIT II

Convex set and convex function - convex optimization problem - quadratic optimization problem - Karush - Kuhn - Tucker (KKT) necessary and sufficient conditions for quadratic programming problem.

UNIT III

Interior point method for convex optimization - linear programming - primal and dual problems and basic concept of multi - objective optimization problem. Concept of functional, different types of performance indices, Euler - Lagrange equation.

UNIT IV

Calculus of variation to optimal control problem - Fundamental concepts, functionals of a single function, functional involving several independent functions, necessary conditions for optimal control, linear regulator problems. Linear quadractic regulator, remarks on weighting matrices, solution of Riccati equation.

UNIT V

Frequency domain interpretation of linear quadratic regulator, robustness studies. Dynamic programming, Pontrygin's minimum principle, time optimal control, concept of system and signal norms, statement of problem and its solution.

Text Books:

1. Jasbir S. Arora, Introduction to optimum design, Elesevier, 2005.
2. A Ravindran, K.M. Ragsdell, and G.V. Reklaitis, Engineering optimization : Methods and applications, Wiley India Edition.
3. Donald E.Kirk, Optimal Control Theory an Introduction, Prentice - Hall Network series - First edition, 1970.

Reference Books:

1. D.S. Naidu, Optimal control systems, CRC Press, First edition, 2002.
2. Arturo Locatelli, Optimal control: An Introduction, Birkhauser Verlag, 2001.
3. S.H.Zak, Systems and Control, Indian Edition , Oxford University, 2003.
4. Niclas Anreasson, Anton Evgrafov and Michael Patriksson, An introduction to continuous optimization, Overseas Press (India) Pvt. Ltd.

15D22108 CONTROL SYSTEMS LAB

List of Experiments

1. Determination of Transfer functions of an Electrical System.
2. Time Response Characteristics of a Second order System (Typical RLC network).
3. Characteristics of Synchros:
   - (a) Synchro transmitter characteristics.
   - (b) Implementation of error detector using synchro pair.
4. Determination of Magnetic Amplifier Characteristics with different possible connections.
5. Process Control Simulator:
   - (a) To determine the time constant and transfer function of first order process.
   - (b) To determine the time response of closed loop second order process with Proportional Control.
   - (c) To determine the time response of closed loop second order process with Proportional-Integral Control.
   - (d) To determine the time response of closed loop second order process with Proportional-Integral-Derivative Control.
   - (e) To determine the effect of disturbances on a process.
6. To study the compensation of the second order process by using:
   - (a) Lead Compensator.
   - (b) Lag Compensator.
   - (c) Lead- Lag Compensator
7. Realization of AND, OR, NOT gates, other derived gates and ladder logic on Programmable Logic Controller with computer interfacing.
8. To determination of AC servomotor Characteristics.
9. To study the position control of DC servomotor with P, PI control actions.
10. Analog Computer:
    - (a) To examine the operation of potentiometer and adder.
    - (b) To examine the operation of integrator.
    - (c) To solve a second order differential equation.

15D22105 PLC & AUTOMATION

Unit-I:
PLC Basics: PLC system, I/O modules and interfacing, CPU processor, programming Equipment, programming formats, construction of PLC ladder diagrams, Devices connected to I/O modules.

PLC Programming: Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation.

Unit-II:
Digital logic gates, programming in the Boolean algebra system, conversion examples
Ladder Diagrams for process control: Ladder diagrams & sequence listings, ladder diagram construction and flowchart for spray process system.

Unit-III:
PLC Resisters: Characteristics of Registers, module addressing, holding registers, Input Registers, Output Registers.

PLC Functions: Timer functions & Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions

Unit-IV:
Data Handling functions: SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR & Sweep functions and their applications

Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two-axis & three axis Robots with PLC, Matrix functions.

Unit-V:
Analog PLC operation: Analog modules& systems, Analog signal processing, Multi bit Data Processing, Analog output Application Examples, PID principles, positions indicator with PID control, PID Modules, PID tuning, PID functions.

Reference Books:

1. Programmable Logic Controllers- Principles and Applications by John W. Webb & Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers- Programming Method and Applications –JR.Hackworth &F.D Hackworth Jr. –Pearson, 2004

15D22106 ROBUST CONTROL

UNIT I: Review of classical feedback control

Review of classical feedback control: The control problem, Transfer functions, Deriving linear models, Frequency response, Feedback control, Closed loop stability, Evaluating closed - loop performance, Controller design, Loop shaping, Shaping closed loop transfer functions.

UNIT II: Introduction to Multivariable Control

Transfer functions for MIMO systems, Multivariable frequency response analysis, Control of multivariable plants, Introduction to robustness, General control problem formulation.
Elements of Linear System Theory: Internal stability of feedback systems, Stabilizing controllers, System norms, Input - Output Controllability, perfect control and plant inversion, Constraints on S and T.

UNIT III: Limitations on Performance

In SISO Systems: Limitations imposed by RHP - zeros, Limitations imposed by RHP - poles, Performance requirements imposed by disturbances and commands, Limitations imposed by input constraints, Limitations imposed by uncertainty.

In MIMO Systems: Constraints on S and T, Functional Controllability, Limitations imposed by RHP - zeros, Limitations imposed by RHP - poles, Performance requirements imposed by disturbances, Limitations imposed by input constraints, Limitations imposed by uncertainty.

UNIT IV: Uncertainty and Robustness for SISO Systems

Introduction to robustness, Representing uncertainty, parametric uncertainty, Representing uncertainty in the frequency domain, SISO robust stability, SISO robust performance, Examples of parametric uncertainty.

UNIT V: Robust Stability, Performance Analysis and Control System Design

General control formulation with uncertainty, Representing uncertainty, Obtaining P, N and M, Definition of robust stability and performance, Robust stability of the MΔ - structure, RS for complex unstructured uncertainty, RS with structured uncertainty: Motivation, The structured singular value and RS, Properties and computation of μ, Robust performance, Application: RP with input uncertainty, μ - synthesis and DK - iteration, Further remarks on μ. Trade - offs in MIMO feedback design, LQG control, H_2 and H_∞ control, H_∞ loop - shaping design.

Text Books:

1. Sigurd Skogestad and Ian Postlethwaite, Multivariable Feedback Control Analysis and Design - John Wiley & Sons Ltd., 2nd Edition, 2005.
2. D. W. Gu, P. Hr. Petkov and M. M. Konstantinov "Robust Control Design with MATLAB" Spring - Verlag London Ltd., 2005.

References:

1. Kennin Zhou, "Robust and Optimal Control", Prentice Hall, Engle wood Cliffs, New Jersy.

15D23103 MACHINE MODELING & ANALYSIS

UNIT -I: Basic Principles for Machine Analysis: Magnetically Coupled Circuits, Machine Windings and Air-Gap MMF, Winding Inductances and Voltage Equations.
Modeling And Analysis Of DC Machines:
Elementary DC Machine, Voltage and Torque Equations, Types of DC Machines, Permanent and Shunt DC Motors, Time-Domain and State-Equations,

UNIT-II: Reference Frame Theory: Introduction to Transformations, Equations of Transformations, Change of Variables, and Transformation to an Arbitrary Reference Frame, Commonly used Reference Frames, Transformation between Reference Frames, Steady-State Phasor Relationships and Voltage Equations

UNIT-III: Modeling & Dynamic Analysis of Three Phase Induction Machines: Voltage and Torque Equations in Machine Variables, Voltage and Torque Equations in Arbitrary Reference Frame, Steady-State Analysis and its Operation.
Free Acceleration Characteristics viewed from Various Reference Frames, Dynamic Performance during Sudden Changes in Load Torque, Dynamic Performance during A Three-Phase Fault at the Machine Terminals

UNIT-IV: Modeling & Dynamic Analysis of Synchronous Machine: Voltage and Torque Equations in Machine Variables, Voltage Equations in Arbitrary and Rotor Reference Frame, Torque Equations in Substitute Variable, Steady-State Analysis and its Operation.
Dynamic Performance of Synchronous Machine, Three-Phase Fault, Comparison of Actual and Approximate Transient Torque Characteristics, Equal Area Criteria.

UNIT -V: Modeling of Special Machines*: Modeling of Permanent Magnet Brushless DC Motor Operating principle – Mathematical modeling of PM Brushless DC motor - PMDC Motor Drive Scheme.*

Text books

1. Krause, Wasynczuk, Sudhoff, **Analysis of Electric Machinery and Drive Systems**: 2nd Edition, Wiley Interscience Publications, 2002.

2. P. C. Krause, Analysis of Electric Machinery, McGraw Hill-1980

15D22107 EMBEDDED SYSTEMS

UNIT- I Embedded Systems: Processor & Memory Organization
Embedded System, types of Embedded System, Requirements of Embedded System, Issues in Embedded software development, Applications, Structural units in a processor, Processor selection, Memory devices, Memory selection, Memory Allocation & Map; Interfacing

UNIT-II: Devices, Device Drivers & Buses for Device Networks
I/O devices, Timer & Counter devices, Serial Communication, Communication between devices using different buses, Device drives, Parallel and serial port device drives in a system, Interrupt servicing mechanism, context and periods for context switching, Deadline and Interrupt Latency.

UNIT-III: Real Time Operating Systems
Operating System Services, I/O Subsystems, Network Operating Systems, Real-Time and Embedded System Operating Systems, Interrupt Routines and Handling of Interrupt Source Call in RTOS, RTOS task scheduling Models, Interrupt Latency and Response Times of the Tasks, Performance Metric in Scheduling Models for different Tasks, IEEE standard POSIX 1003.1b Functions for standardization of RTOS and Inter_Task Communication Functions, List of basic actions in a Preemptive Scheduler and Expected Times taken at a processor, Fifteen-point Strategy for Synchronization between the Processes, ISRs, OS Functions and Tasks for Resource Management, OS Security Issues, Mobile OS.

UNIT-IV: Hardware-Software Co-Design in an Embedded System
Embedded System Project Management, Embedded system design and co-design issues in system development process, design cycle in development phase for Embedded System, Uses of its Emulator and In-Circuit Emulator (ICE), Use of Software tools for development of an Embedded System, Use of scopes and Logic Analyzers for system Hardware tests, Issues in Embedded system design

UNIT-V: Applications
Embedded System Design for: An Adaptive Cruise Control System in a car, Smart Card, Digital Clock, Battery-operated Smartcard Reader, Automated Meter Reading (AMR) System, Digital Camera

TEXT BOOKS:

1. Raj Kamal, “Embedded Systems : Architecture, Programming and Design”, Tata McGraw Hill, 2005
2. Shibu. K. V, “Introduction to Embedded Systems”, Tata McGraw Hill, 2009

15D22201 ADAPTIVE CONTROL

Unit – I

Introduction, Block Diagram of an Adaptive System, Effects of Process Variations on System Performance, Types of Adaptive Schemes, Formulation of the Adaptive Control Problem, Abuses of Adaptive Control, Least Squares Method and Regression Models for Parameter Estimation – Theorems, Estimating Parameters in Models of Dynamic Systems, The Finite Impulse Response Model, The Transfer Function Model, and The Stochastic Model.

Unit – II

Block Diagram of Deterministic Self Tuning Regulator (STR), Pole Placement Design – Process Model, Model Following, Causality Conditions. Indirect STRs – Estimation, Continuous - Time STRs, Direct STRs – Minimum Phase Systems, Adaptive Control Algorithm, Feed Forward Control, Non Minimum Phase Systems – Adaptive Control Algorithm, Algorithm For Hybrid STR.

Unit – III

Design of Minimum Variance and Moving - Average Controllers, Stochastic STR – Indirect STR, Algorithm for Basic STR, Theorems on Asymptotic Properties. Unification of Direct STRs, Generalized Direct Self Tuning Algorithm, Self Tuning Feed Forward Control. Linear Quadratic STR – Theorems on LQG Control, Algorithms for Indirect LQG – STRs Based on Spectral Factorization and Riccati Equation.

Unit –IV

Model Reference Adaptive System (MRAS), The MIT Rule, Block Diagram of an MRAS for adjustment of Feed Forward Gain based on MIT Rule. Adaptation Gain – Methods for determination. Design of MRAS using Lyapunov Theory – Block Diagram of an MRAS based on Lyapunov Theory for a First Order System. Proof of The Kalman – Yakubovich Lemma, Adjustment Rules for Adaptive Systems, Relation between MRAS and STR.

Unit – V

Gain Scheduling – Principle, Block Diagram, Design of Gain Scheduling Controllers, Nonlinear Transformations, Block Schematic of a Controller based on Nonlinear Transformations. Application of Gain Scheduling for Ship Steering, Flight Control. Self Oscillating Adaptive System (SOAS) – Principle, Block Diagram, Properties of The Basic SOAS, Procedure for Design of SOAS. Industrial Adaptive Controllers and applications.

Text books

1. K.J.Astrom and Bjorn Wittenmark, Adaptive control, Pearson Edu., 2nd Edn.
2. Sankar Sastry, Adaptive control.

References

1. V.V.Chalam, Adaptive Control System - Techniques & Applications, Marcel Dekker Inc.
2. Miskhin and Braun, Adaptive control systems, MC Graw Hill
3. Karl Johan Åström, Graham Clifford Goodwin, P. R. Kumar, Adaptive Control, Filtering and Signal Processing
4. G.C. Goodwin, Adaptive control.

5. Narendra and Anna Swamy, Stable Adaptive Systems.

15D22202 DIGITAL CONTROL SYSTEMS

UNIT – I

Digital Control Systems – Block Schematic, Examples, Signal Forms, Advantages and Disadvantages of Digital Control, Data Conversion and Quantization, Sampling Process. Reconstruction of Original Signals from Sampled Signals - Sampling Theorem, Ideal Low – Pass Filter. Impulse Sampling and Data Hold-Transfer Function of Zero - Order Hold and First-Order Hold, Frequency Response Characteristics.

UNIT – II

The Z-Transform and Inverse Z Transform, Z - Transform Method for Solving Difference Equations. The Pulse Transfer Function (PTF) – PTFs of Closed - Loop Systems, Digital Controllers, Digital PID Controller and Digital Control Systems. Mapping Between The S – Plane and Z – Plane - Primary and Complementary Strips. Stability Analysis – Jury Test, Bilinear Transformation and Routh Criterion, Lyapunov Method for LTI Discrete time systems. Design based on the Frequency Response Method and Bilinear Transformation.

UNIT – III

State Space Representations of Discrete - Time Systems, Solution of The Time - Invariant Discrete-Time State Equation, State Transition Matrix , Z-Transform Approach to The Solution of State Equation , Discritization of Continuous- Time State- Space Equations , Controllability and Observability of Discrete- Time Systems, Conditions, Principle of Duality.

UNIT – IV

Design via Pole Placement – Necessary and Sufficient Condition for Pole Placement, Ackerman's Formula, Dead Beat Response, Design of Dead Beat Controllers. State Observers – Necessary and Sufficient Condition for State Observation. Full Order State Observer, Error Dynamics of The Full Order State Observer, Design of Prediction Observers –Ackerman's Formula.

UNIT – V

Design of Minimum-Order Observer, Observed- State Feedback Control System with Minimum-Order Observer. Diophantine Equation, Polynomial Equation approach to Control System Design. Design of Model Matching Control Systems.

Text books:

1. K. Ogata, Discrete Time Control Systems, PHI/Addison - Wesley Longman Pte. Ltd., India, Delhi, 1995.
2. B.C Kuo, Digital Control Systems, 2nd Edition, Oxford Univ Press, Inc., 1992.

Reference Books:

1. .F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems, Addison - Wesley Longman, Inc., Menlo Park, CA , 1998.
2. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, India, 1997.
3. C. H. Houpis and G.B. Lamont, Digital Control Systems, McGraw Hill, 1985.
4. John S. Baey, Fundamentals of Linear State Space Systems, Mc. Graw – Hill, 1st edition
5. Bernard Fried Land, Control System Design, Mc. Graw – Hill, 1st edition
6. Dorsay, Continuous and Discrete Control Systems, McGraw - Hill.

15D22203 INTELLIGENT ALGORITHMS

UNIT I: Introduction and motivation. Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule - based systems, the AI approach. Knowledge representation. Expert systems. Data Pre - Processing: Scaling, Fourier transformation, principal - component analysis and wavelet transformations.

UNIT II

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch - Pitts neuron model, simple perceptron, Adaline and Madaline, Feed - forward Multilayer Perceptron. Learning and Training the neural network. Networks: Hopfield network, Self - organizing network and Recurrent network. Neural Network based controller, Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab / Neural Network toolbox.

UNIT III

Genetic Algorithm: Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other than GA search techniques like tabu search and ant - colony search techniques for solving optimization problems.

UNIT IV

Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to Fuzzy logic modeling and control of a system. Fuzzification, inference and defuzzification. Fuzzy knowledge and rule bases.

UNIT V

Fuzzy modeling and control schemes for nonlinear systems. Self - organizing fuzzy logic control. Implementation of fuzzy logic controller using Matlab fuzzy - logic toolbox. Stability analysis of fuzzy control systems. Intelligent Control for SISO/MIMO Nonlinear Systems. Model Based Multivariable Fuzzy Controller.

Text Books

1. Simon Haykins, Neural Networks: A comprehensive Foundation, Pearson Edition, 2003.
2. T.J.Ross, Fuzzy logic with Fuzzy Applications, Mc Graw Hill Inc, 1997.
3. David E Goldberg, Genetic Algorithms.

References

1. M.T.Hagan, H. B. Demuth and M. Beale, Neural Network Design, Indian reprint, 2008.
2. Fredric M.Ham and Ivica Kostanic, Principles of Neurocomputing for science and Engineering, McGraw Hill, 2001.
3. N.K. Bose and P.Liang, Neural Network Fundamentals with Graphs, Algorithms and Applications, Mc - Graw Hill, Inc. 1996.
4. Yung C. Shin and Chengying Xu, Intelligent System - Modeling, Optimization and Control, CRC Press, 2009.
5. N.K.Sinha and Madan M Gupta, Soft computing & Intelligent Systems - Theory & Applications, Indian Edition, Elsevier, 2007.
6. John Yen and Reza Langari, Fuzzy logic Intelligence, Control, and Information, Pearson Education, Indian Edition, 2003.
7. Witold Pedrycz, Fuzzy Control and Fuzzy Systms, Overseas Press, Indian Edition, 2008.

15D22204 ESTIMATION OF SIGNALS AND SYSTEMS

UNIT I

Review of Probability theory and random variable - random process - A Family of Transfer function Models. Equation Error Model Structure, Linear Regression. ARMAX Model Structure, Other Equation. Error - Type Model Structures - Output Error Model Structure - Box - Jenkins Model Structure - A General Family of Model Structures - Continuous Time Black - Box Model.

UNIT II

Recursive least squares (RLS), Consistency of estimation, Weighted LS.

UNIT III

Parametric models - LS estimation, bias - Generalized Least Squares (GLS) and Instrumental Variable (IV) method. Persistently exciting input signal - Likelihood functions and Maximum Likelihood Estimation (MLE) - Singular Value Decomposition (SVD).

UNIT IV

Kalman filter, State estimation using Kalman filter, Parameter estimation using Kalman filter. Extended Kalman Filters for continuous and discrete time systems, State and Parameter estimations.

UNIT V

Multi - variable system representation, controllability and observability indices; Feedback system identification. Stochastic Approximation Algorithm (STA); Model order and structure determination.

Text Books:

1. Papoulis and Pillai, Probability, Random Variables and Stochastic Process, McGraw Hill, 2002.
2. Jerry M. Mendel, Lessons in Estimation Theory for Signal Processing, Communications, and Control, Prentice - Hall, 1995.

References:

1. Karl J Astrom, Introduction to Stochastic Control Theory, Mathematics in Series and Engg., Vol. 70.
2. Michel Verhaegen and Vincent Verdult, Filtering and System Identification A Least Squares Approach, Cambridge Univ. Press, 2007.
3. M.S. Grewal and A.P. Andrews, Kalman Filtering Theory and Practice Using Matlab, John Wiley, 2008.

15D54201 RESEARCH METHODOLOGY

(Audit Course)

UNIT I

Meaning of Research – Objectives of Research – Types of Research – Research Approaches – Guidelines for Selecting and Defining a Research Problem – research Design – Concepts related to Research Design – Basic Principles of Experimental Design.

UNIT II

Sampling Design – steps in Sampling Design –Characteristics of a Good Sample Design – Random Sampling Design.

Measurement and Scaling Techniques-Errors in Measurement – Tests of Sound Measurement – Scaling and Scale Construction Techniques – Time Series Analysis – Interpolation and Extrapolation.

Data Collection Methods – Primary Data – Secondary data – Questionnaire Survey and Interviews.

UNIT III

Correlation and Regression Analysis – Method of Least Squares – Regression vs Correlation – Correlation vs Determination – Types of Correlations and Their Applications

UNIT IV

Statistical Inference: Tests of Hypothesis – Parametric vs Non-parametric Tests – Hypothesis Testing Procedure – Sampling Theory – Sampling Distribution – Chi-square Test – Analysis of variance and Co-variance – Multi-variate Analysis.

UNIT V

Report Writing and Professional Ethics: Interpretation of Data – Report Writing – Layout of a Research Paper – Techniques of Interpretation- Making Scientific Presentations in Conferences and Seminars – Professional Ethics in Research.

Text books:

1. **Research Methodology:Methods and Techniques – C.R.Kothari, 2nd Edition,New Age International Publishers.**
2. **Research Methodology: A Step by Step Guide for Beginners- Ranjit Kumar, Sage Publications (Available as pdf on internet)**
3. **Research Methodology and Statistical Tools – P.Narayana Reddy and G.V.R.K.Acharyulu, 1st Edition,Excel Books,New Delhi.**

REFERENCES:

1. **Scientists must Write - Robert Barrass (Available as pdf on internet)**
2. **Crafting Your Research Future –Charles X. Ling and Quiang Yang (Available as pdf on internet)**

15D22207 CONTROL SYSTEMS SIMULATION LAB

List of Experiments

The following experiments may be implemented in MATLAB/SIMULINK environment.

1. Preliminary Transformations:
    (a) Transfer function to State space models vice- versa.
    (b) Conversion of Continuous to Discrete time systems vice- versa.
    (c) Verification of controllability and observablity of a given system.
2. Design of state feedback controllers.
3. Stability analysis of a given system using:
    (a) Root Locus.
    (b) Bode plot.
    (c) Lyapunov stability.
4. Implementation of Kalman Filter.
5. Implementation of Least squares error method.
6. Implementation of PID controller and its effects on a given system.
7. Design of Lead, Lag, Lead- Lag compensators using frequency domain analysis.
8. Construction of Simulink model for an Induction motor.

Note: At least four problems may be implemented from the following

9. Solving steady state Ricatti Equation.
10. Construction of Simulink model foe single area and multi area Power system.
11. Solving an optimal control problem using Ricatti equation.
12. Implementation of Full order and minimum order Observer.
13. Implementation of Back-Propagation Algorithm.
14. Implementation of simple Fuzzy controller.
15. Implementation of storage and recall algorithm of Hopfield network model.

15D22205 REAL TIME SYSTEMS

UNIT-I:

Introduction to Real - time systems: Typical examples of RTS, Characteristic features of RT applications. Structural, Functional and Performance requirement of Reactive RTS. Distinctive features from Non - RT and Off - line system. Modeling RTS: Representation of time, Concurrency and Distributedness in discrete event systems.

UNIT-II:

Hierarchical representation of complex DES. Input, Output and Communication. Examples of modeling practical systems as RT DES. Modeling programs as RTS. Analyzing RTS: Analyzing logical properties of DES such as Reachability, Deadlock etc. Analyzing timing related properties, Specification and Verification of RT DES properties.

UNIT-III:

Temporal logic, Model checking. Example of checking safety and timing properties of industrial systems. Requirements and features of real - time Computing Environments: Real - time Operating Systems, Interrupts, clock, Device support.

UNIT-IV:

Real time System, Multi tasking, Static and Dynamical Scheduling of resource Allocation, Real - time Programming.

UNIT-V:

Real - time process and applications, Distributed Real - time systems.

TEXTBOOK:

1. Jane W S Liu, “Real- Time Systems”, Pearson publications, 1st edition, 2006.

REFERENCE BOOK:

1. Rajib Mall**, “**Real-Time Systems: Theory and Practice”, Pearson Education India**,** 2009.

15D21207 SOLAR ENERGY CONVERSION SYSTEMS

UNIT-I: SOLAR CELL FUNDAMENTALS

Place of PV in world energy scenario – need for sustainable energy sources – current status of Renewable energy sources – place of photovoltaic in Energy supply – solar radiation – the sun and earth movement – angle of sunrays on solar collectors – sun tracking – estimating solar radiation empirically – measurement of solar radiation - Fundamentals of semiconductors – charge carriers and their motion in semiconductor – P-N Junction Diode – an introduction to solar cells.

UNIT-II: DESIGN OF SOLAR CELLS

Upper limits of cell parameters – short circuit current, open circuit voltage, fill factor, efficiency – losses in solar cells – model of a solar cell, effect of series and shunt resistance on efficiency , effect of solar radiation on efficiency – solar cell design – design for high I_{SC} – Design for high V_{OC} – design for high FF – Analytical techniques.

UNIT-III: SOLAR PHOTOVOLTAIC MODULES

Solar PV Modules from solar cells – series and parallel connection of cells – mismatch in module – mismatch in series connection – hot spots in the module , bypass diode – mismatching in parallel diode – design and structure of PV modules – number of solar cells in a module, wattage of modules, fabrication of PV module – PV module power output.

UNIT-V: BALANCE OF SOLAR PV SYSTEMS

Basics of Electromechanical cell – factors affecting performance – batteries for PV systems – DC to DC converters – charge controllers – DC to AC converters(Inverters) – Maximum Power Point tracking (MPPT) – Algorithms for MPPT.

UNIT V: PV SYSTEM DESIGN AND APPLICATIONS

Introduction to solar PV systems – standalone PV system configuration – design methodology of PV systems – design of PV powered DC fan without battery, standalone system with DC load using MPPT, design of PV powered DC pump, design of standalone system with battery and AC/DC load – wire sizing in PV system – precise sizing of PV systems – Hybrid PV systems – grid connected PV systems.

TEXT BOOKS:

1. “Solar Photovoltaics Fundamentals, Technologies and Applications” by Chetan singh solanki, PHI publications.

REFERENCES:

1. Solar Energy Fundamentals and applications by H.P. Garg, J. Prakash “Tata McGraw- Hill publishers I[st] edition”
2. S.Rao & B.B.Parulekar, “Energy Technology”, 4th edition, Khanna publishers, 2005.

15D21208 WIND ENERGY CONVERSION SYSTEMS

UNIT-I: FUNDAMENTALS OF WIND TURBINES

Historical background - basics of mechanical to electrical energy conversion in wind energy - types of wind energy conversion devices – definition - solidity, tip speed ratio, power coefficient, wind turbine ratings and specifications - aerodynamics of wind rotors - design of the wind turbine rotor

UNIT-II: WIND TURBINE CONTROL SYSTEMS & SITE ANALYSIS

Power speed characteristics - torque speed characteristics - Pitch angle control – stall control – power electronic control – Yaw control – Control strategy – wind speed measurements – wind speed statistics – site and turbine selection.

UNIT-III: BASICS OF INDUCTION AND SYNCHRONOUS MACHINES

The Induction Machine – constructional features - equivalent circuit model - performance characteristics - saturation characteristics – dynamic d-q model – the wound – field synchronous machine – the permanent magnet synchronous machine – power flow between two synchronous sources – induction generator versus synchronous generator

UNIT-IV: GRID CONNECTED AND SELF-EXCITED INDUCTION GENERATOR OPEARTION

Constant – voltage, constant – frequency- single output system –double output system with current converter & voltage source inverter – equivalent circuits – reactive power and harmonics – reactive power compensation – variable – voltage, variable – frequency generation – the self- excitation process – circuit model for the self – excited induction generator – analysis of steady state operation – the steady state characteristics – the excitation requirement – effect of a wind generator on the network .

UNIT-V: WIND GENERATION WITH VARIABLE-SPEED TURBINES AND APPLICATION

Classification of schemes – operating area – induction generators – doubly fed induction generator – wound field synchronous generator – the permanent magnet generator – Merits and limitations of wind energy conversion systems – application in hybrid energy systems – diesel generator and photovoltaic systems – wind photovoltaic systems.

TEXT BOOKS:

1. S.N.Bhadra,D.Kastha, S.Banerjee, “ wind electrical systems” Oxford University Press.

REFERENCES:

1. S.Rao & B.B.Parulekar, “Energy Technology”, 4th edition, Khanna publishers, 2005.
2. “Renewable Energy sources & Conversion Technology” by N.K.Bansal, Manfred Kleemann, Michael Meliss. Tata Mcgraw Hill Publishers.

15D22206 PROCESS DYNAMICS AND CONTROL

UNIT I:

Introduction to Process Control, Representative Process Control Problems, Illustrative Example-A Blending process, Classification of Control Strategies, Hierarchy of Process Control activities, Dynamic versus Steady - state Models, The rationale of Dynamic Process models, General Modeling Principles, Dynamic model of CSTR, Degrees of freedom analysis, Linearization of Non-linear models. Processes with time delays, Approximation of Higher - Order transfer functions, Interacting and Non interacting Processes, Multiple - Input, Multiple - Output (MIMO) Processes.

UNIT II:

Basic Control modes, Features of PID Controllers, Typical process responses with Feedback control, Digital versions of PID Controllers, Transducers and Transmitters, Final Control elements, Accuracy in Instrumentation, Guidelines for selection of Controlled, Manipulated and Measured variables, Process safety and Process Control, Block diagram representation of Blending process composition control system, General stability criterion, Routh Stability criterion for time delay systems, Direct substitution method.

UNIT III:

Performance Criteria for Closed - Loop Systems, Model - based design methods - Direct Synthesis Method, Internal Model Control, Controller tuning relations, Controllers with two degrees of freedom, Online controller tuning, trial and error tuning, Continuous Cycling Method, Relay auto tuning, Process Reaction Curve Method, Guidelines for Common Control Loops, troubleshooting Control Loops.

UNIT IV:

Introduction to Feed forward Control, Ratio Control, Feed forward Controller Design based on Steady - State Models, Controller Design based on Dynamic Models, Tuning Feed forward Controllers, Configurations for Feed forward - Feedback Control, Cascade control, Design considerations for cascade control, Time delay compensation, Block diagram of the Smith predictor, Inferential control, Selective control/Override systems.

UNIT V:

Multi loop and multivariable control: Process Interactions and Control Loop Interactions, Pairing of Controlled and Manipulated Variables, Bristols RGA method, Calculation of the RGA, Methods for obtaining the steady state gain matrix, Measure of Process Interactions and Pairing recommendations, Dynamic considerations, Extensions of the RGA analysis, Singular value analysis, Selection of manipulated variables and Controlled variables, Tuning of multi loop PID Control systems, Decoupling and multi variable control strategies, Strategies for Reducing Control Loop Interactions.

Text Books:

Dale E. Seborg, University of California, Santa Barbara, Thomas F. Edgar, University of Texas at Austin, Duncan A. Mellichamp, University of California, Santa Barbara, Process Dynamics and Control, John Wiley & Sons, 2nd Edition, 2004.

References:

Brian Roffel, Ben Betlem, Process Dynamics and Control Modeling for Control and Prediction, John Wiley & Sons Ltd., 2007.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR
JNTUA COLLEGE OF ENGINEERING (AUTONOMOUS) :: ANANTHAPURAMU
Ananthapuramu – 515 002, Andhra Pradesh, India

Course Structure of R21 Academic Regulations for M.Tech (Regular) Programs with effect from AY 2021-2022

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CONTROL SYSTEMS

I SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week L	T	P	Credits
1	21D22101	Modern Control Systems	PC	3	0	0	3
2	21D22102	Adaptive Control Theory	PC	3	0	0	3
3	**Professional Elective – I**						
	21D22103	Estimation of Signals & Systems	PE	3	0	0	3
	21D22104	Real Time & Embedded Systems					
	21D22105	Advanced Digital Signal Processing					
4	**Professional Elective – II**						
	21D22106	Intelligent Control Systems	PE	3	0	0	3
	21D22107	Networked Control Systems					
	21D22108	Digital Control Systems					
5	21D11109	Research Methodology and IPR	MC	2	0	0	2
6	21D11110	English for Research Paper Writing	AC	2	0	0	0
	21D11111	Value Education					
	21D11112	Pedagogy Studies					
7	21D22109	Control Systems Lab	PC	0	0	4	2
8	21D22110	Control Systems Simulation Lab	PC	0	0	4	2
Total				**16**	**00**	**08**	**18**

CONTROL SYSTEMS

II SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week			Credits
				L	T	P	
1	21D22201	Non-linear Control Systems	PC	3	0	0	3
2	21D22202	Process Dynamics & Control	PC	3	0	0	3
3	**Professional Elective – III**						
	21D22203	Robotics & Control	PE	3	0	0	3
	21D22204	Optimal Control					
	21D22205	Performance Assessment & Plant Wide Control					
4	**Professional Elective – IV**						
	21D21106	Solar & Wind Energy Conversion Systems	PE	3	0	0	3
	21D22206	Biomedical Measurement Systems					
	21D22207	Robust Control					
5	21D11209	Technical Seminar	PR	0	0	4	2
6	21D11210	Disaster Management	AC	2	0	0	0
	21D11211	Constitution of India					
	21D11212	Stress Management by Yoga					
7	21D22208	Process Control Lab	PC	0	0	4	2
8	21D22209	Advanced Control Systems Simulation Lab	PC	0	0	4	2
Total				**14**	**00**	**12**	**18**

CONTROL SYSTEMS

III SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week L	T	P	Credits
1	**Professional Elective – V**						
	21D22301	Industrial Drives & Control	PE	3	0	0	3
	21D22302	Data Driven Control					
	21D22303	Guidance Strategies for Autonomous Vehicles					
2	**Open Elective**						
	21D20301	Waste to Energy	OE	3	0	0	3
3	21D22304	Dissertation Phase – I	PR	0	0	20	10
4	21D00301	Co-Curricular Activities	PR				2
Total				**06**	**00**	**20**	**18**

IV SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week L	T	P	Credits
1	21D22401	Dissertation Phase – II	PR	0	0	32	16
Total				**00**	**00**	**32**	**16**

Course Code	21D22101	MODERN CONTROL SYSTEMS (21D22101)	L	T	P	C
Semester	I		3	0	0	3

Course Objectives: Student will be able to

- Remember and understand the concept of state space representation, Solution of state equation, STM, linearization of nonlinear systems, controllability and observability concepts, principles of duality, concepts of optimal and Lyapunov stability.
- Apply the above concepts to analyze controllability, Observability and pole placement by state feedback.
- Analyze the concept of regulator, stability and sensitivity using various methods and disturbance rejection.
- Design Full order observer and reduced order observer.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand the state space representation, controllability and observability concepts, principles of duality, concepts of optimal and Lyapunov stability.
- Apply the state equations, pole placement by state feedback.
- Analyze controllability & observability of state models.
- Design full order observer and reduced order observer.

UNIT - I | **STATE VARIABLE DISCRIPTION** | **Lec Hrs: 9**

Introductory matrix algebra and linear Vector Space, State space representation of systems-Linearization of a non-linear System- Solution of state equations- Evaluation of State Transition Matrix (STM).

UNIT - II | **TRANSFORMATION, POLEPLACEMENT AND CONTROLLABILITY** | **Lec Hrs: 10**

Similarity transformation and invariance of system properties due to similarity transformations-Minimal realization of SISO- SIMO and MISO transfer functions-Discretization of a continuous time state space model- Conversion of state space model to transfer function model using Fadeeva algorithm- Fundamental theorem of feedback control - Controllability and Controllable canonical form - Pole assignment by state feedback using Ackermann‘s formula– Eigen structure assignment problem.

UNIT - III | **OPTIMAL CONTROL** | **Lec Hrs: 10**

Linear Quadratic Regulator (LQR) problem and solution of algebraic Riccati equation using Eigen value and Eigen vector methods- iterative method- Controller design using output feedback.

UNIT - IV | **OBSERVERS** | **Lec Hrs: 9**

Observability and observable canonical form-Design of full order observer using Ackermann‘s formula -Bass Gura algorithm- Duality between controllability and observability- Full order Observer based controller design- Reduced order observer design.

UNIT - V | **STABILITY ANALYSIS AND SENSITIVITY** | **Lec Hrs: 10**

Internal stability of a system- Stability in the sense of Lyapunov- Asymptotic stability of linear time invariant continuous and discrete time systems- Solution of Lyapunov type equation- Model decomposition and decoupling by state feedback- Disturbance rejection- sensitivity and complementary sensitivity functions.

Textbooks:

1. K. Ogata, "Modern Control Engineering", Prentice Hall, India, 5th edition, 2010.
2. T. Kailath, "Linear Systems", Perntice Hall, 2016.
3. N.K. Sinha, "Control Systems", New Age International, 4th edition, 2013.

Reference Books:

1. Panos J Antsaklis, and Anthony N.Michel,"LinearSystems", New-age international (P) LTD,Publishers, 2009.
2. John JDAzzoand C. H. Houpis, "LINEAR Control System Analysis And Design With Matlae", Marcel Dekker, Inc., 5Th edition, 2003.
3. B.N.Dutta, "Numerical Methods for linear Control Systems", Elsevier Publication, 2007.
4. C.T. Chen "Linear System Theory and Design- Oxford Series 3rdEdition, 1998.
5. Richard C. Dorf and Robert H. Bishop, "Modern Control Systems", 12th Edition, Pearson Edu., India, 2014

Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22102	ADAPTIVE CONTROL THEORY (21D22102)	L	T	P	C
Semester	I		3	0	0	3

Course Objectives: Student will be able to

- Understand the basic concepts of Adaptive control and types, Self Tuning Regulator and MRAS and gain scheduling.
- To analyze Gain scheduling and applications of Adaptive control
- To Apply Gain Scheduling concepts in real life applications.
- To develop adaptive control algorithms

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand the basic concepts of Adaptive control system, types, formulation of control problem and various dynamic models.
- Analyse the Adaptive models like STR and MRAS
- Design of STR based control algorithms and MRAS based control algorithms
- Apply the Adaptive control concepts for various applications.
- Evaluate the given dynamical system performance using Adaptive control laws

UNIT - I	**BASICS OF ADAPTIVE SYSTEMS**	**Lec Hrs: 10**

Preface to adaptive systems- Block Diagram of an Adaptive System- Effects of Process Variations on System Performance-Types of Adaptive Schemes-Formulation of the Adaptive Control Problem-Abuses of Adaptive Control-Least Squares Method and Regression Models for Parameter Estimation – Theorems-Estimating Parameters in Models of Dynamic Systems-The Finite Impulse Response Model-The Transfer Function Model and The Stochastic Model

UNIT - II	**SELF TUNNING REGULATOR**	**Lec Hrs: 09**

Block Diagram of Deterministic Self Tuning Regulator (STR)-Pole Placement Design – Process Model-Model Following-Causality Conditions-Indirect STRs – Estimation-Continuous - Time STRs-Direct STRs – Minimum Phase Systems-Adaptive Control Algorithm-Feed Forward Control- Non Minimum Phase Systems – Adaptive Control Algorithm-Algorithm For Hybrid STR.

UNIT - III	**TYPES OF SELF TUNING REGULATORS**	**Lec Hrs: 10**

Design of Minimum Variance and Moving - Average Controllers-Stochastic STR – Indirect STR-Algorithm for Basic STR-Theorems on Asymptotic Properties-Unification of Direct STRs-Generalized Direct Self Tuning Algorithm-Self Tuning Feed Forward Control-Linear Quadratic STR – Theorems on LQG Control- Algorithms for Indirect LQG – STRs Based on Spectral Factorization and Riccati Equation.

UNIT - IV	**MODEL REFERENCE ADAPTIVE SYSTEM**	**Lec Hrs: 11**

Model Reference Adaptive System (MRAS)-The MIT Rule- Block Diagram of an MRAS for adjustment of Feed Forward Gain based on MIT Rule-Adaptation Gain – Methods for determination- Design of MRAS using Lyapunov Theory – Block Diagram of an MRAS based on Lyapunov Theory for a First Order System-Proof of The Kalman – Yakubovich Lemma-Adjustment Rules for Adaptive Systems-Relation between MRAS and STR.

UNIT - V	**GAIN SCHEDULING**	**Lec Hrs: 10**

Gain Scheduling – Principle-Block Diagram-Design of Gain Scheduling Controllers-Nonlinear Transformations-Block Schematic of a Controller based on Nonlinear Transformations-Application of Gain Scheduling for Ship Steering-Flight Control. Self Oscillating Adaptive System (SOAS) – Principle-Block Diagram-Properties of The Basic SOAS-Procedure for Design of

SOAS- Industrial Adaptive Controllers and applications.

Textbooks:

1. K.J.Astrom and Bjorn Wittenmark, "Adaptive control", Pearson Edu., 2nd Edn. 2008.
2. Sankar Sastry,Marc Bodson," Adaptive control stability, convergence and robustness" Prentic – Haii,1st Edition,2008.

Reference Books:

1. V.V.Chalam, "Adaptive Control System - Techniques & Applications" Marcel Dekker Inc. 2nd Edition, 1987.
2. Miskhin and Braun," Adaptive control systems", MC Graw Hill ,1st Edition.1961.
3. Karl Johan Åström, Graham Clifford Goodwin, P. R. Kumar, "Adaptive Control, Filtering and Signal Processing", 2nd Edition, 2008.

Online Learning Resources:

1. https://nptel.ac.in/courses/108/102/108102113/

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22103	ESTIMATION OF SIGNALS AND SYSTEMS (21D22103) (PE-I)	L	T	P	C
Semester	I		3	0	0	3

Course Objectives: Student will be able to

- Understand probability theory, types of model structure, Multi variable system representation, controllability and observability indices
- Apply the concepts of recursive least square, weighted least square, generalized least square, likelihood and maximum likelihood estimation
- Analyze SVD, Kalman filter and extended Kalman filter
- Create Approximation Algorithm (STA)

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand probability theory, types of model structure, Multi variable system representation, controllability and observability indices
- Apply the concepts of recursive least square, weighted least square, generalized least square, likelihood and maximum likelihood estimation
- Analyze SVD, Kalman filter and extended Kalman filter
- Create Approximation Algorithm (STA)

UNIT - I	Review of Probability Theory and Model Structures	Lec Hrs: 11

Review of Probability theory and random variable - random process - A Family of Transfer function Models-Equation Error Model Structure-Linear Regression- ARMAX Model Structure-Other Equation-Error - Type Model Structures - Output Error Model Structure - Box - Jenkins Model Structure - A General Family of Model Structures - Continuous Time Black - Box Model.

UNIT - II	Recursive Least Squares	Lec Hrs: 07

Recursive least squares (RLS)-Consistency of estimation-Weighted LS.

UNIT - III	Parametric Models	Lec Hrs: 10

Parametric models - LS estimation-bias - Generalized Least Squares (GLS) and Instrumental Variable (IV) method-Persistently exciting input signal - Likelihood functions and Maximum Likelihood Estimation (MLE) - Singular Value Decomposition (SVD).

UNIT - IV	Kalman Filter and Extented Kalman Filter	Lec Hrs: 10

Kalman filter-State estimation using Kalman filter- Parameter estimation using Kalman filter-Extended Kalman Filters for continuous and discrete time systems - State and Parameter estimations.

UNIT - V	Multi Variable System Representation	Lec Hrs: 10

Multi variable system representation-controllability and observability indices-Feedback system identification-Stochastic Approximation Algorithm (STA)-Model order and structure determination.

Textbooks:

1. Papoulis and Pillai, Probability, Random Variables and Stochastic Process, McGraw Hill, 4^{th} edition. 2017
2. Jerry M. Mendel, Lessons in Estimation Theory for Signal Processing, Communications, and Control, Prentice - Hall, 2^{nd} edition. 1995.

Reference Books:
1. Karl J Astrom, Introduction to Stochastic Control Theory, Mathematics in Series and Engg., Vol. 70, 1st edition. 1970. 2. Michel Verhaegen and Vincent Verdult, Filtering and System Identification A Least Squares Approach, Cambridge Univ. Press, 1st edition. 2012. 3. M.S. Grewal and A.P. Andrews, Kalman Filtering Theory and Practice Using Matlab, John Wiley, 4th edition. 2014.
Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22104	REAL TIME & EMBEDDED SYSTEMS (21D22104) (PE-I)	L	T	P	C
Semester	I		3	0	0	3

Course Objectives: Student will be able to

- To preamble real-time systems.
- To enumerate the mathematical model of the system.
- To develop real-time algorithm for task scheduling.
- To understand the working of real-time operating systems and real-time database.
- To work on design and development of protocols related to real-time communication

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand microprocessors, microcontrollers and digital signal processors
- Understand the pc based data acquisition; analog to digital signal conversion andvice versa
- Understand the digital logic circuits used with embedded systems
- Design embedded systems

UNIT - I	System Design:	Lec Hrs: 9

Definitions-Classifications and brief overview of micro-controllers-microprocessors and DSPs-Embedded processor architectural definitions- Typical applicationscenario of embedded systems.

UNIT - II	Data Acquisition Basics:	Lec Hrs: 10

Introduction to data acquisition on PC- Sampling fundamentals-Input/output techniques and buses-ADC- DAC- Digital I/O- counters and timers- DMA- Software and hardware installation-Calibration- Resolution- Data acquisition interface requirements.

UNIT - III	Interface Issues Related to Embedded Systems:	Lec Hrs: 10

Interface Issues Related to Embedded Systems: A/D- D/A converters-timers- actuators- power-FPGA- ASIC- diagnostic port.

UNIT - IV	Techniques for Embedded Systems:	Lec Hrs: 9

State Machine and state tables in embedded design- Simulation and Emulation of embedded systems- High-level language descriptions of S/W for embedded system- Java embedded system design.

UNIT - V	Real Time Models & Case Studies	Lec Hrs: 10

Real time Models- Language and Operating Systems- Event based- process based and graphbased models-Petrinet models – Real time languages – The real time kernel- OS tasks- task states- task scheduling- interrupt processing-clocking communication and synchronization- control blocks-memory requirements and control- kernel services.

Case Studies: Discussion of specific examples of complete embedded systems using mc68 HC11-mc8051- ADSP2181-PIC series of microcontroller.

Textbooks:

11. K.J.Astrom and Bjorn Wittenmark, “Adaptive control”, Pearson Edu., 2nd Edn. 2008.
2. Sankar Sastry, Adaptive control 1st Edition.2008.

Reference Books:

1. V.V.Chalam, Adaptive Control System - Techniques & Applications, Marcel Dekker Inc. 2nd Edn. 1987.

2. Miskhin and Braun, Adaptive control systems, MC Graw Hill ,1st Edition.1961. 3. Karl Johan Åström, Graham Clifford Goodwin, P. R. Kumar, Adaptive Control, Filtering and Signal Processing, 2nd Edn. 2008.
Online Learning Resources:

Course Code	21D22105	ADVANCED DIGITAL SIGNAL PROCESSING	L	T	P	C
Semester	I	(21D22105) (PE-I)	3	0	0	3

Course Objectives: Student will be able to

- Understanding the fundamental characteristics of signals and systems.
- Development of the mathematical skills to solve problems involving convolution, filtering modulation and sampling.
- Knowledge of frequency-domain representation and analysis concepts using Fourier analysis tools, Z-transform.
- **Realization of FIR and IIR digital filters**

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understanding of different transformation techniques.
- Compute the z-transform of a sequence, identify its region of convergence, and compute the inverse z-transform by partial fractions.
- Compute the linear and circular convolutions of discrete-time sequences.
- Realize various filters and finding solution for various filter designs.

UNIT - I	Preface To Advanced Digital Signal Processing	Lec Hrs: 9

Short introduction- Analog to digital and Digital to Analog conversion-sampled and Hold circuit-Continuous time Fourier Transforms- Discrete-time signals and systems- Discrete-time Fourier transform- its properties and applications- Fast Fourier Transform (in time-domain and Frequency domain)-IDFT and its properties.

UNIT - II	Z- Transforms And Digital Filter Structures	Lec Hrs: 12

Definition and properties, Rational z-transforms- Region of convergence of a rational z-Transform- The inverse z- Transform- Z-Transform properties- Computation of the convolution sum of finite-length sequences- The transfer function.

Digital Filter Structures: Block Diagram representation-Equivalent structures- Basic FIR Digital Filter structures- Basic IIR Digital Filter structures- Realization of Basic structures using MATLAB-All pass filters- Computational complexity of Digital filter structures.

UNIT - III	IIR Digital Filter Design	Lec Hrs: 10

Preliminary considerations- Bilinear transformation method of IIR Filter design- Design of low pass IIR Digital filters- Design of High pass- Band pass and band stop IIR digital filters-Spectral Transformations of IIR filter- IIR digital filter design using MATLAB-Computer aided design of IIR digital filters.

UNIT - IV	FIR Digital Filter Design	Lec Hrs: 10

Preliminary considerations- FIR filter design based on windowed Fourier series- Computer aided design of Equiripple Linear phase FIR filters-Design of Minimum phase FIR filters- FIR digital filter design using MATLAB- Design of computationally efficient FIR digital filters.

UNIT - V	Analysis Of Finite Word Length Effects	Lec Hrs: 12

The quantization process and errors- quantization of Fixed point numbers- Quantization of floating point numbers- Analysis of coefficient quantization effects- Analysis of arithmetic round off errors- Low sensitivity digital filters- Reduction of product round off errors using error feedback-Round off errors in FFT algorithms- The basic sample rate alteration devices- Multi rate structures for sampling rate conversion- Multistage design of decimator and interpolator-The Polyphase decomposition- Arbitrary-rate sampling rate converter-Nyquist Filters and some applications of digital signal processing.

Textbooks:

1. S.K. Mitra**, Digital Signal Processing**-, Tata McGraw-Hill, Third Edition, 2007.
2. B.P. Lathi, **Principle of Signal Processing and Linear Systems**-, Oxford International Student Version, 1st edition ,2009.
3. M. Mondal and A Asif, **Continuous and Discrete Time Signals and Systems**, Cambridge, 1st edition ,2007.

Reference Books:

1. Li Tan, **Digital Signal Processing- Fundamentals and Applications**-, Indian reprint, Elsevier, 3st edition ,2018.
2. Alan V. Oppenheim, Ronald W. Schafer, and John R.Buck, **Discrete- Time Signal Processing**-, Pearson Edu, 3rd edition 2010.

Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22106	INTELLIGENT CONTROL SYSTEMS (21D22106) (PE-II)	L	T	P	C
Semester	I		3	0	0	3

Course Objectives: Student will be able to

- Understand the basic concepts of Intelligent control, architecture, data pre-processing, Artificial Neural Networks, Fuzzy Logic Control System, finally Heuristic Optimization techniques
- Apply the concepts of ANN, Fuzzy and Heuristic Optimization to develop various algorithms and control techniques
- Analyze Linear and Non-Linear systems by applying ANN, Fuzzy and Heuristic Optimization techniques
- Design Intelligent Control Systems for various applications with the help of ANN, Fuzzy and Optimization methods

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand the basic concepts of Intelligent control, architecture, data pre-processing, Artificial Neural Networks, Fuzzy Logic Control System, finally Heuristic Optimization techniques
- Apply the concepts of ANN, Fuzzy and Heuristic Optimization to develop various algorithms and control techniques
- Analyze Linear and Non-Linear systems by applying ANN, Fuzzy and Heuristic Optimization techniques
- Design Intelligent Control Systems for various applications with the help of ANN, Fuzzy and Optimization methods

UNIT - I	Intelligent Control Overview & Data Pre-processing	Lec Hrs: 9

Overview and motivation. Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule - based systems, the AI approach. Knowledge representation. Expert systems. Data Pre - Processing: Scaling, Fourier transformation, principal - component analysis and wavelet transformations.

UNIT - II	Artificial Neural Networks	Lec Hrs: 10

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch - Pitts neuron model, simple perceptron, Adaline and Madaline, Feed - forward Multilayer Perceptron. Learning and Training the neural network. Networks: Hopfield network, Self - organizing network and Recurrent network. Neural Network based controller, Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab / Neural Network toolbox.

UNIT - III	Heuristic Optimization Technioques	Lec Hrs: 10

Genetic Algorithm: Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other than GA search techniques like tabu search and ant - colony search techniques for solving optimization problems.

UNIT - IV	Fuzzy Logic System	Lec Hrs: 9
Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to Fuzzy logic modeling and control of a system. Fuzzification, inference and defuzzification. Fuzzy knowledge and rule bases.		
UNIT - V	**Fuzzy Controller Design & Analysis**	**Lec Hrs: 10**
Fuzzy modeling and control schemes for nonlinear systems. Self - organizing fuzzy logic control. Implementation of fuzzy logic controller using Matlab fuzzy - logic toolbox. Stability analysis of fuzzy control systems. Intelligent Control for SISO/MIMO Nonlinear Systems. Model Based Multivariable Fuzzy Controller.		

Textbooks:

1. Bose and Liang "Artificial Neural Networks" , Tata McGraw Hill, 1st edition ,1996.
2. Huaguang Zhang, Derong Liu "Fuzzy Modeling and Fuzzy Control", Birkhauser Publishers, 26st edition, 2006.
3. S. N. Sivanandam and S. N. Deepa, "Principles of Soft Computing", John Wiley & Sons, 2nd edition 2011.

Reference Books:

1. M. Nørgaard, O. Ravn, N. K. Poulsen, L. K. Hansen "Neural Networks for Modelling and Control of Dynamic Systems", Springer-Verlag, 1st edition, 2002
2. Laxmidhar Behera and Indrani Kar "Intelligent Systems and Control", Oxford, 1st edition, 2009.
3. Kosco B,Prentice "Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence", Hall of India, New Delhi, 1st edition, 1994.

Online Learning Resources:

Prof. Kevin M. Passino resources of MATLAB codes (http://eewww.eng.ohio-state.edu/~passino/ICbook/ic_code.html)

Course Code	21D22107	NETWORKED CONTROL SYSTEMS	L	T	P	C

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Semester	I	(21D22107) (PE-II)	3	0	0	3

Course Objectives: Student will be able to

- Understand the basic concepts of Industrial communication system, Internet, Network Security, Various Measurements and IOT
- Apply the concepts in order to measure various control system related issues
- Analyze the performance of networked control systems with the help of various measurements
- Create networked control systems with the concepts of interfacing, internet, network security and feedback control

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand the basic concepts of Industrial communication system, Internet, Network Security, Various Measurements and IOT
- Apply the concepts in order to measure various control system related issues
- Analyze the performance of networked control systems with the help of various measurements
- Create networked control systems with the concepts of interfacing, internet, network security and feedback control

UNIT - I	Industrial Communication Systems:	Lec Hrs: 9

Interface - Introduction, Principles of interface- serialinterface and its standards-Parallel interfaces and buses

UNIT - II	Internet & Physical Layer Aspects	Lec Hrs: 10

Preface to Internet: Origin of Internet – Overview of TCP / IP layers – IP addressing – DNS – Packet switching – Routing – SMTP, POP, MIME, NNTP, ftp, Telnet, HTML, HTTP, URL, SNMP, RFCs, FYIs – STDs. Physical Layer Aspects: Backbone network – Trunks, Routers, Bridges – Access network –MODEMs, WILL, ISDN, XDSL, VSAT.

UNIT - III	Network Layer Aspects and Network Security:	Lec Hrs: 10

IPVG, Mobile IP – IPSEC – IPSO – Public key cryptography – digital signature standard – firewall – Secure socket Layer SSL – Secure Data Network System SDNS – Network layer security Protocol NLSP – Point to point Tunneling Protocol PPTP – SHTTP.

UNIT - IV	Measurements Through Internet:	Lec Hrs: 10

Web based data acquisition – Monitoring of plant parameters through Internet – Calibration of measuring instruments through Internet. Internet based Control: Virtual laboratory – Web based Control – Tuning of controllersthrough Internet. Wireless sensors for measurement and feedback control.

UNIT - V	Internet of Things	Lec Hrs: 10

Internet of Things (IoT) –overview- basic elements- use of control system- communication and feedback control Demonstration usingappropriate tools in the laboratory.

Textbooks:

1. Internet Based Control Systems, Shuang-Hua Yang, Springer, 1st Edition 2011.
2. Internet Working with TCP/IP, Douglas E. Camer, 3rd Edition, Prentice Hall, 1999.

Reference Books:

1. TCP/IP Illustrated, Richard Stevens, Addison Wesley, 1st Edition 1999.

2.	Internet Cryptography, Richard E. Smith, Addison Wesley, 1st Edition 1999.
Online Learning Resources:	

Course Code	21D22108	DIGITAL CONTROL SYSTEMS	L	T	P	C
Semester	I	(21D22108) (PE-II)	3	0	0	3

Course Objectives: Student will be able to

1. Understand basics of DCS, Z & Inverse Z-Transforms, Controlability, Observability, Pole Placement and observers.
2. Analyze Data conversion, quantization, sampling process, stability analysis using Zury test, Routh criteria and Lyapunov function
3. Apply Z-Transforms to solving state equations and ackermans formulation for finding feedback gain and observer gain matrices
4. Design full order observer, reduced order observer, prediction observer and dead beat controller

Course Outcomes (CO): After completing the course, the student should be able to:

1. Understand basics of DCS, Z & Inverse Z-Transforms, Controlability, Observability, Pole Placement and observers.
2. Analyze Data conversion, quantization, sampling process, stability analysis using Zury test, Routh criteria and Lyapunov function
3. Apply Z-Transforms to solving state equations and Ackermans formula for finding feedback gain and observer gain matrices
4. Design full order observer, reduced order observer, prediction observer and dead beat controller

UNIT - I	Basics of Digital Control Systems	Lec Hrs: 9

Digital Control Systems – Block Schematic, Examples, Signal Forms, Advantages and Disadvantages of Digital Control, Data Conversion and Quantization, Sampling Process. Reconstruction of Original Signals from Sampled Signals - Sampling Theorem, Ideal Low – Pass Filter. Impulse Sampling and Data Hold-Transfer Function of Zero - Order Hold and First-Order Hold, Frequency Response Characteristics.

UNIT - II	Transformation Techniques	Lec Hrs: 10

The Z-Transform and Inverse Z Transform, Z - Transform Method for Solving Difference Equations. The Pulse Transfer Function (PTF) – PTFs of Closed - Loop Systems, Digital Controllers, Digital PID Controller and Digital Control Systems. Mapping Between The S – Plane and Z – Plane - Primary and Complementary Strips. Stability Analysis – Jury Test, Bilinear Transformation and Routh Criterion, Lyapunov Method for LTI Discrete time systems. Design based on the Frequency Response Method and Bilinear Transformation.

UNIT - III	State Space Representations of DCS	Lec Hrs: 10

State Space Representations of Discrete - Time Systems, Solution of The Time - Invariant Discrete- Time State Equation, State Transition Matrix , Z-Transform Approach to The Solution of State Equation , Discritization of Continuous- Time State- Space Equations , Controllability and Observability of Discrete- Time Systems, Conditions, Principle of Duality.

UNIT - IV	Design Via Pole Placement and Full Order Observer	Lec Hrs: 9

Design via Pole Placement – Necessary and Sufficient Condition for Pole Placement, Ackerman's Formula, Dead Beat Response, Design of Dead Beat Controllers. State Observers – Necessary and Sufficient Condition for State Observation. Full Order State Observer, Error Dynamics of The Full Order State Observer, Design of Prediction Observers –Ackerman's Formula.

UNIT - V	Design of Minimum Order Observer	Lec Hrs: 10

Design of Minimum-Order Observer, Observed- State Feedback Control System with Minimum-Order Observer. Diophantine Equation, Polynomial Equation approach to Control System Design. Design of Model Matching Control Systems.

Textbooks:

1. K. Ogata, Discrete Time Control Systems, Pearson Education India, 2nd Edition, 2015.
2. B.C Kuo, Digital Control Systems, Oxford Univ Press, USA, 2nd Edition, 1995.

Reference Books:

1 .F. Franklin, J.D. Powell, and M.L. Workman, Digital control of Dynamic Systems, AddisonWesley Longman, Inc., Menlo Park, CA , 1st 1998.
2. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, India, 1st 1997.
3. C. H. Houpis and G.B. Lamont, Digital Control Systems, McGraw Hill, 1st 1985.
4. John S. Baey, Fundamentals of Linear State Space Systems, Mc. Graw – Hill, 1st edition
5. Bernard Fried Land, Control System Design, Mc. Graw – Hill, 1st edition
6. Dorsay, Continuous and Discrete Control Systems, McGraw - Hill.1st Edition

Online Learning Resources:

https://www.coursebuffet.com/sub/electrical-engineering/525/digital-control-system

Course Code	21D22109	CONTROL SYSTEMS LAB (21D22109)	L	T	P	C
Semester	I		0	0	4	2

Course Objectives: To make the student

- Familiarize with the modeling of dynamical systems
- Interpret the characteristics of control components like ac servo motor, synchro and magnetic amplifier.
- Analyze and simulate the stability using MATLAB software
- Design the compensators.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand the stability of an Electrical, mechanical and other physical systems
- Analyze the physical systems represented in transfer function.
- Apply the control components like ac servo motor, synchro and magnetic amplifier.
- Design controllers, compensators using MATLAB software

List of Experiments:

1. Determination of Transfer functions of an Electrical System.
2. Time Response Characteristics of a Second order System (Typical RLC network).
3. Characteristics of Synchros:
   (a) Synchro transmitter characteristics.
   (b) Implementation of error detector using synchro pair.
4. Determination of Magnetic Amplifier Characteristics with different possible connections.
5. Process Control Simulator:
   (a) To determine the time constant and transfer function of first order process.
   (b) To determine the time response of closed loop second order process with Proportional Control.
   (c) To determine the time response of closed loop second order process with Proportional-Integral Control.
   (d) To determine the time response of closed loop second order process with Proportional-Integral-Derivative Control.
   (e) To determine the effect of disturbances on a process.
6. To study the compensation of the second order process by using:
   (a) Lead Compensator.
   (b) Lag Compensator.
   (c) Lead- Lag Compensator
7. Realization of AND, OR, NOT gates, other derived gates and ladder logic on Programmable
   Logic Controller with computer interfacing.
8. To determination of AC servomotor Characteristics.
9. To study the position control of DC servomotor with P, PI control actions.
10. Analog Computer:
    (a) To examine the operation of potentiometer and adder.
    (b) To examine the operation of integrator.
    (c) To solve a second order differential equation.

Course Code	21D22110	CONTROL SYSTEMS SIMULATION LAB (21D22110)	L	T	P	C
Semester	I		0	0	4	2

Course Objectives: To make the student

- Will have a strong knowledge on MATLAB software.
- To study the concept of time response and frequency response of the system
- Students get the basic knowledge on practical control system applications on machines & electronic devices.
- This course aims to familiarize with the modeling of dynamical systems, to simulate and analyze the stability of the system using MATLAB.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- to illustrate modeling and simulation of any system.
- To Classify and evaluate the performance parameters of a system and then with simulation prepare an advance tool to modify the values of the parameter of the system in order to meet the desired need.
- to compute or to predict the characteristics of a system by visualizing experimental data and its graphical representation.
- Evaluate possible causes of discrepancy in practical experimental observations in comparison to theory by introducing the concepts of different stability theorems

List of Experiments:

The following experiments may be implemented in MATLAB/SIMULINK environment.

1. Preliminary Transformations:
   (a) Transfer function to State space models vice- versa.
   (b) Conversion of Continuous to Discrete time systems vice- versa.
   (c) Verification of controllability and observablity of a given system.
2. Design of state feedback controllers.
3. Stability analysis of a given system using:
   (a) Root Locus.
   (b) Bode plot.
   (c) Lyapunov stability.
4. Implementation of Kalman Filter.
5. Implementation of Least squares error method.
6. Implementation of PID controller and its effects on a given system.
7. Design of Lead, Lag, Lead- Lag compensators using frequency domain analysis.
8. Construction of Simulink model for an Induction motor.

Note: At least four problems may be implemented from the following

9. Solving steady state Ricatti Equation.
10. Construction of Simulink model foe single area and multi area Power system.
11. Solving an optimal control problem using Ricatti equation.
12. Implementation of Full order and minimum order Observer.
13. Implementation of Back-Propagation Algorithm.
14. Implementation of simple Fuzzy controller.
15. Implementation of storage and recall algorithm of Hopfield network model.

Course Code		Research Methodology and IPR	L	T	P	C
Semester	I		2	0	0	2

Course Objectives: To make the student

Course Outcomes (CO): Student will be able to		
• Understand research problem formulation. • Analyze research related information • Follow research ethics • Understand that today's world is controlled by Computer, Information • Technology, but tomorrow world will be ruled by ideas, concept, and creativity. • Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular. • Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.		
UNIT – I		Lecture Hrs: 8
Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations		
UNIT - II		Lecture Hrs: 4
Effective literature studies approaches, analysis Plagiarism, Research ethics		
UNIT - III		Lecture Hrs: 5
Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee		
UNIT - IV		Lecture Hrs: 8
Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.		
UNIT - V		Lecture Hrs: 7
Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.		
Textbooks:		
1. Stuart Melville and Wayne Goddard, "Research methodology: An introduction for science & engineering students'" 2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction" 3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide• for beginners" 4.		
Reference Books:		

1. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
2. Mayall, "Industrial Design", McGraw Hill, 1992.
3. Niebel, "Product Design", McGraw Hill, 1974.
4. Asimov, "Introduction to Design", Prentice Hall, 1962.
5. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
6. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code		RESEARCH PAPER WRITING SKILLS (Audit Course-I)	L	T	P	C
Semester	I		2	0	0	0

Course Objectives: To make the student

- Understand that how to improve your writing skills and level of readability.
- Learn about what to write in each section.
- Understand the skills needed when writingaTitleEnsurethegoodqualityofpaperatveryfirst-timesubmission.

Course Outcomes (CO): Student will be able to

UNIT – I		Lecture Hrs: 8

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs andSentences,BeingConciseandRemovingRedundancy,AvoidingAmbiguity and Vagueness

UNIT - II		Lecture Hrs: 6

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction

UNIT - III		Lecture Hrs: 5

Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

UNIT - IV		Lecture Hrs: 6

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature

UNIT - V		Lecture Hrs: 7

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions. useful phrases, how to ensure paper is as good as it could possibly be the first-time submission

Textbooks:

1. Goldbort R(2006) Writing for Science, Yale University Press(available on Google Books).
2. Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press.
3. Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM Highman's book.
4. AdrianWall work, English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011.

Reference Books:

Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22201	NONLINEAR CONTROL SYSTEMS (21D22201)	L	T	P	C
Semester	II		3	0	0	3

Course Objectives: Student will be able to

- Understand linear and nonlinear systems, describing function, overview of system analysis and Stability
- Apply Lyaponov functions to nonlinear systems
- Analyze the systems with Lyapunov stability theorem and Popov's stability criterion.
- Application of nonlinear systems such as the ball and beam, flight control, magnetic levitation and robotic manipulator.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand linear and nonlinear systems, describing function, overview of system analysis and Stability
- Apply Lyaponov functions to nonlinear systems
- Analyze the systems with Lyapunov stability theorem and Popov's stability criterion.
- Application of nonlinear systems such as the ball and beam, flight control, magnetic levitation and robotic manipulator.

UNIT - I	System Nonlinearities	Lec Hrs: 9

Linear versus nonlinear systems - Describing function analysis: Fundamentals- common nonlinearities (saturation, dead – zone- on - off non – linearity- backlash- hysteresis) and their describing functions.

UNIT - II	Describing Function	Lec Hrs: 10

Describing function analysis of nonlinear systems- Reliability of describing method analysis- Compensation and design of nonlinear system using describing function method- Phase plane analysis: Phase portraits-Singular points characterization- Analysis of non - linear systems using phase plane technique- Existence of limit cycles.

UNIT - III	Concept of Stability and Theorems	Lec Hrs: 10

Concept of stability-Zero - input and BIBO stability- stability in the sense of Lyapunov and absolute stability- Stability in the small and stability in the large-Lyapunov stability definitions- First method of Lyapunov- Second (or direct) method of Lyapunov stability theory for continuous and discrete time systems- Aids to generate Lyapunov function – Krasovskii's theorem- Variable gradient method.

UNIT - IV	Stability Analysis	Lec Hrs: 10

Aizerman's and Kalman's conjecture-Construction of Lyapunov function - Methods of Aizerman-Zubov- Variable gradient method- Lure problem. Popov's stability criterion- generalized circle criterion- Kalman - Yakubovich - Popov Lemma- Popov's hyper stability theorem.

UNIT - V	Applications of Non-Linear Controller	Lec Hrs: 9

Concept of variable - structure controller and sliding control- reaching condition and reaching mode- implementation of switching control laws- Reduction of chattering in sliding and steady state mode- Some design examples of nonlinear systems such as the ball and beam-flight control-magnetic levitation and robotic manipulator etc.

Textbooks:

1. J. E. Slotine and Weiping LI, Applied Nonlinear Control, Prentice Hall,
2. Hassan K. Khalil, Nonlinear Systems, Prentice Hall, 1996.

Reference Books:
1. Sankar Sastry, Nonlinear Systems Analysis, Stability and Control. 2. M. Vidyasagar, Nonlinear Systems Analysis, Prentice - Hall International editions,1993.
Online Learning Resources:
1. https://nptel.ac.in/courses/108/102/108102113/

Course Code	21D22202	PROCESS DYNAMICS & CONTROL (21D22202)	L	T	P	C
Semester	II		3	0	0	3

Course Objectives: Student will be able to

- Understand process control problems, Basic control modes, linearization of Non-linear models, SISO and MIMO Processes, Block diagram representation of blending processes
- Apply various controllers to different processes
- Analyze dynamic modeling of CSTR, general stability criteria, performance of process control systems, ratio control, feed forward control, cascade control , decoupling and multivariable strategies and singular valve analysis
- Design ratio control, cascade controller and feed forward controller.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand process control problems, Basic control modes, linearization of Non-linear models, SISO and MIMO Processes, Block diagram representation of blending processes
- Apply various controllers to different processes
- Analyze dynamic modelling of CSTR, general stability criteria, performance of process control systems, ratio control, feed forward control, cascade control , decoupling and multivariable strategies and singular valve analysis
- Design ratio control, cascade controller and feed forward controller.

UNIT - I	**Process controller models**	Lecture Hrs:10

Preface to Process Control, Representative Process Control Problems-Illustrative Example-A Blending process, Classification of Control Strategies, Hierarchy of Process Control activities, Dynamic versus Steady - state Models, The rationale of Dynamic Process models, General Modeling Principles - Dynamic model of CSTR - Degrees of freedom analysis - Linearization of Non-linear models - Processes with time delays - Approximation of Higher - Order transfer functions, Interacting and Non interacting Processes, Multiple - Input, Multiple - Output (MIMO) Processes.

UNIT - II	**PID Controllers, Transducers and Stability**	Lecture Hrs:10

Basic Control modes - Features of PID Controllers - Typical process responses with Feedback control - Digital versions of PID Controllers - Transducers and Transmitters - Final Control elements, Accuracy in Instrumentation, Guidelines for selection of Controlled, Manipulated and Measured variables - Process safety and Process Control, Block diagram representation of Blending process composition control system - General stability criterion - Routh Stability criterion for time delay systems - Direct substitution method.

UNIT - III	**Performance analysis of process control systems**	Lecture Hrs:9

Performance Criteria for Closed - Loop Systems, Model - based design methods - Direct Synthesis Method, Internal Model Control - Controller tuning relations - Controllers with two degrees of freedom - Online controller tuning - trial and error tuning - Continuous Cycling Method - Relay auto tuning - Process Reaction Curve Method - Guidelines for Common Control Loops - troubleshooting Control Loops.

UNIT - IV	**Ratio Control, Feed forward controller and Cascade controller**	Lecture Hrs:10

Introduction to Feed forward Control, Ratio Control - Feed forward Controller Design based on Steady - State Models, Controller Design based on Dynamic Models - Tuning Feed forward Controllers, Configurations for Feed forward - Feedback Control, Cascade control - Design considerations for cascade control - Time delay compensation - Block diagram of the Smith predictor - Inferential control - Selective control/Override systems.

UNIT - V	**Multi loop and multivariable control**	Lecture Hrs:9

Process Interactions and Control Loop Interactions - Pairing of Controlled and Manipulated Variables - Bristols RGA method - Calculation of the RGA - Methods for obtaining the steady state gain matrix - Measure of Process Interactions and Pairing recommendations - Dynamic considerations - Extensions of the RGA analysis - Singular value analysis - Selection of manipulated variables and Controlled variables - Tuning of multi loop PID Control systems - Decoupling and multi variable control strategies - Strategies for Reducing Control Loop Interactions.

Textbooks:

1. Dale E. Seborg, Santa Barbara, Thomas F. Edgar, Duncan A. Mellichamp, Santa Barbara, Process Dynamics and Control, John Wiley & Sons, 4th Edition, 2016.

Reference Books:

1. Brian Roffel, Ben Betlem, Process Dynamics and Control Modeling for Control and Prediction, John Wiley & Sons Ltd., 2007.

Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22203	ROBOTIC & CONTROL (21D22203) (PE-III)	L	T	P	C
Semester	II		3	0	0	3

Course Objectives: Student will be able to

- Understand spatial descriptions and transformations, manipulator kinematics, velocities and static forces, linear and non linear control of manipulators
- Apply Newton's equation, Eulers Equation to frame force equations and control problems for manipulators
- Analyze mass distribution, Euler dynamic formulations, Lagrangian Formulation of manipulator Dynamics, Formulating manipulator dynamics and Present industrial robot control scheme.
- Modelling and control of a single joint manipulator

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand spatial descriptions and transformations, manipulator kinematics, velocities and static forces, linear and non linear control of manipulators
- Apply Newton's equation, Eulers Equation to frame force equations and control problems for manipulators
- Analyze mass distribution, Euler dynamic formulations, Lagrangian Formulation of manipulator Dynamics, Formulating manipulator dynamics and Present industrial robot control scheme.
- Modelling and control of a single joint manipulator

UNIT - I	Spatial Descriptions and Transformations	Lec Hrs: 9

Introduction - Descriptions: positions, orientations and frames - Mappings: Changing descriptions from frame to frame - Operators: translations, rotations, transformations, Transformation arithmetic - Transform equations - More on representation of orientation - Transformation of free vectors - Computational considerations.

UNIT - II	Manipulator Kinematics	Lec Hrs: 10

Introduction - Link description - Link connection description - convention for affixing frames to links - Manipulator kinematics - Actuator space, Joint space and Cartesian space - Examples: Kinematics of two industrial robots - Computational considerations. Introduction – Solvability - The notation of manipulator subspace when n<6 - Algebraic Vs. Geometric - Algebraic solution by reduction to polynomial - Pieper's solution when three axes intersect - Examples of inverse manipulator kinematics - The standard frames - SOLVE - ing a manipulator - Repeatability and accuracy - Computational considerations.

UNIT - III	Jacobians: Velocities And Static Forces	Lec Hrs: 12

Introduction - Notation for time varying position and orientation - Linear and Rotation of velocity of rigid bodies - More on angular velocity - Motion of the links of a Robot - Velocity " propagation" from link to link – Jacobians – Singularities - Static forces in Manipulators - Jacobians in the force domain - Cartesian transformation of velocities and static forces. Introduction - Acceleration of a rigid body - Mass distribution - Newton's Equation, Euler's equation - Iterative Newton –Euler dynamic formulation - Iterative Vs. Closed form - An example of closed form dynamic equations - The structure of the Manipulator dynamic equations

- Lagrangian Formulation of manipulator Dynamics - Formulating manipulator dynamics in Cartesian space - Computational considerations.

UNIT - IV	**Linear Control Of Manipulators**	**Lec Hrs: 9**
Introduction - Feedback and closed loop control - Second order linear systems - Control of second order systems - Control law partitioning – Trajectory - Following control - Disturbance rejection - Continuous Vs. Discrete time control - Modeling and control of a single joint - Architecture of industrial robot controller.		
UNIT - V	**Non - Linear Control And Force Control Of Manipulators**	**Lec Hrs: 12**
Introduction - Nonlinear and time - varying systems - multi - input, Multi - output control systems - The control problem for manipulators - Practical considerations - Present industrial robot control systems - Lyapunov stability analysis - Cartesian based control systems - adaptive control. Introduction - Application of Industrial robots to assembly tasks - A frame work for control in partially constrained tasks - The hybrid position/force control problem - Force control of a mass - spring - The hybrid position / force control scheme - Present industrial robot control scheme.		

Textbooks:

1. John. J. Craig, Introduction to Robotics Mechanics & Control, Pearson/Prentice Hall, 3rd Edition, 2005,
2. Mark W. Sponge, Sethhutchinson and M. Vidyasagar Robot Modeling and Control, Wiley student Edition, 2006.

Reference Books:

1. Tsuneo Yoshikawa, Foundations of Robotics –Analysis and Control, MIT press, 2003
2. Znihua Qu and Drasen M Dawson, Robust Tracking Control of Robot Manipulators, IEEE Press, 1996.
3. J. J. Craig, Adaptive Control of Mechanical Manipulators, Addison Wesley, Reading MA, 1988.

Online Learning Resources:

Course Code	**21D22204**	**OPTIMAL CONTROL (21D22204) (PE-III)**	**L**	**T**	**P**	**C**
Semester	**II**		**3**	**0**	**0**	**3**

Course Objectives: Student will be able to

- To memorize the basic concepts related to optimal control and its position in optimization.
- To calculate the extrema and parameter optimization by the method of Lagrange multipliers and variational calculus and Pontragin's minimum principle.
- To explain the Optimality Principle and Dynamic Programming.
- To estimate an approach for the Hamilton Jacobi-Bellman equation and Linear Optimal Control Problem.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Remember basic concepts related to optimal control and its position in optimization.
- Apply the calculus of extrema and parameter optimization by the method of Lagrange multipliers and variational calculus and Pontragin's minimum principle.
- Understand the Optimality Principle and Dynamic Programming.
- Evaluate an approach for the Hamilton Jacobi-Bellman equation and Linear Optimal Control Problem

UNIT - I — **Lec Hrs: 9**

An overview of optimization problem - concepts and terms related to optimization - constrained and unconstrained problems and their solutions using different techniques.

UNIT - II — **Lec Hrs: 10**

Convex set and convex function - convex optimization problem - quadratic optimization problem - Karush - Kuhn - Tucker (KKT) necessary and sufficient conditions for quadratic programming problem.

UNIT - III — **Lec Hrs: 10**

Interior point method for convex optimization - linear programming - primal and dual problems and basic concept of multi - objective optimization problem - Concept of functional - different types of performance indices - Euler - Lagrange equation.

UNIT - IV — **Lec Hrs: 9**

Calculus of variation to optimal control problem - Fundamental concepts, functionals of a single function - functional involving several independent functions - necessary conditions for optimal control - linear regulator problems - Linear quadractic regulator - remarks on weighting matrices - solution of Riccati equation.

UNIT - V — **Lec Hrs: 10**

Frequency domain interpretation of linear quadratic regulator - robustness studies - Dynamic programming - Pontrygin's minimum principle - time optimal control - concept of system and signal norms - statement of problem and its solution.

Textbooks:
1. Jasbir S. Arora,” Introduction to optimum design”, Elesevier, 2005. 2. A Ravindran, K.M. Ragsdell, and G.V. Reklaitis, “Engineering optimization : Methods and applications”, Wiley India Edition. 3. Donald E.Kirk,” Optimal Control Theory an Introduction”, Prentice - Hall Network series - First edition, 1970.
Reference Books:
1. D.S. Naidu, Optimal control systems, CRC Press, First edition, 2002. 2. Arturo Locatelli, Optimal control: An Introduction, Birkhauser Verlag, 2001. 3. S.H.Zak, Systems and Control, Indian Edition , Oxford University, 2003. 4. Niclas Anreasson, Anton Evgrafov and Michael Patriksson, An introduction to continuous optimization, Overseas Press (India) Pvt. Ltd
Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22205	PERFORMANCE ASSESSMENT & PLANT WIDE CONTROL (21D22205) (PE-III)	L	T	P	C
Semester	II		3	0	0	3

Course Objectives: Student will be able to

- Understand the basic concepts of minimum variance, interactor matrix, feedback controller, plant wide control, Degrees of freedom and optimal control
- Apply the concepts to design minimum variance control, feedback controller, plant wide controller, PID controller and optimum controller
- Analyze performance assessment of various processes through different modes of controllers
- Design overall control system through dynamic modeling, degrees of freedom and different modes of controllers

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand the basic concepts of minimum variance, interactor matrix, feedback controller, plant wide control, Degrees of freedom and optimal control
- Apply the concepts to design minimum variance control, feedback controller, plant wide controller, PID controller and optimum controller
- Analyze performance assessment of various processes through different modes of controllers
- Design overall control system through dynamic modeling, degrees of freedom and different modes of controllers

UNIT - I	Minimum Variance	Lec Hrs: 9

Unitary Interactor Matrices and Minimum Variance Control - Weighted unitary interactor matrices and singular LQ control - Estimation of the Unitary Interactor Matrices - Determination of the order of interactor matrices - Factorization of unitary interactor matrices - Estimation of the interactor matrix under closed-loop conditions - Numerical rank.

UNIT - II	Feedback Controller Performance Assessment:	Lec Hrs: 10

Simple Interactor - Multivariable performance index - Feedback Controller Performance Assessment - Diagonal Interactor - effect of non- minimum phase zeros - Performance assessment with both stochastic and deterministic disturbances - Performance assessment with pure deterministic disturbances.

UNIT - III	Plant wide Control Fundamentals:	Lec Hrs: 10

Introduction - Integrated Processes - Material Recycle - Energy Integration. Effects of Recycle. Time Constants in Recycle Systems - Steady-State Design. Dynamic Controllability.

UNIT - IV	Degrees of Freedom	Lec Hrs: 9

Degrees of freedom – Design, steady operation and control DOF - DOFs for Economic optimum design - Steady economic process operation - Economic CVs for self-optimizing control Economic trade-offs in plant design and steady operation Process Dynamics - PI(D) Control - Controller Tuning and Pairings.

UNIT - V	Optimum Control Design	Lec Hrs: 10
Optimum design and operation of complete plants - Steady state economic optimum design - Steady state optimum operating policy - The bottom-up pairing approach - Systematic top-down plant wide control design procedure - Simple control structure design examples.		
Textbooks:		
1. Process Control Performance Assessment: From Theory to Implementation, Andrzej Ordys, Damien Uduehi, Michael A Johnson, Springer, 1st Edition 2007. 2. Control Performance Management in Industrial Automation, Mohieddine Jelali, Springer, 1st Edition 2013. 3. Plant-wide Process Control, William L. Luyben, Bjorn D. Tyreus, Michael L. Luyben, McGraw Hill, 1st Edition 1998.		
Reference Books:		
1. Performance Assessment of Control Loops: Theory and Applications, Biao Huang and Sirish L. Shah, Springer-Verlag, 1st Edition 1999. 2. Dynamic Modeling, Predictive Control and Performance Monitoring, Biao Huang, Ramesh Kadali, Springer, 1st Edition 2008. 3. Plantwide Control: Recent Developments and Applications, G.P. Rangaiah, Vinay Kariwala, Wiley, 1st Edition 2012.		
Online Learning Resources:		

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D21106	SOLAR & WIND ENERGY CONVERSION SYSTEM (21D21106) (PE-IV)	L	T	P	C
Semester	II		3	0	0	3

Course Objectives: Student will be able to

- To introduce photovoltaic systems and principle of wind turbines
- To deal with various technologies of solar PV cells
- To understand details about manufacture, sizing and operating techniques in solar energy conversion systems.
- To understand the concepts of fixed speed and variable speed, wind energy conversion systems.
- To have knowledge of design considerations and analyze grid integration issues.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Understand the fundamentals of solar cell, Solar PV Modules from solar cells, system types, Standalone PV system configuration, Maximum Power Point tracking (MPPT) and fundamentals the concepts of fixed speed and variable speed, wind energy conversion systems.
- Apply the concept of various technologies of solar PV cells, manufacture, sizing and operating techniques.
- Analyze the concept of Effect of series and shunt resistance on efficiency, Effect of solar radiation on efficiency, Analytical techniques, Hot spots in the module,Algorithms for MPPT
- Design of PV powered DC fan without battery, Standalone system with DC load using MPPT, PV powered DC pump, standalone system with battery and AC/DC load and control principles of Wind turbine.

UNIT - I	Solar & Wind Fundamentals	Lec Hrs: 10

Need for sustainable energy sources –solar radiation – the sun and earth movement – angle of sunrays on solar collectors – sun tracking – estimating solar radiation – measurement of solar radiation. Types of wind energy conversion devices – definition - solidity, tip speed ratio, power coefficient, wind turbine ratings and specifications - aerodynamics of wind rotors - design of the wind turbine rotor.

UNIT - II	Solar Photovoltaic Modules	Lec Hrs: 10

Solar PV Modules from solar cells – model of a solar cell, effect of series and shunt resistance on efficiency, effect of solar radiation on efficiency - series and parallel connection of cells – mismatch in module – mismatch in series connection – hot spots in the module , bypass diode – mismatching in parallel diode – design and structure of PV modules – number of solar cells in a module, wattage of modules, fabrication of PV module – PV module power output.

UNIT - III	PV System Design And Applications	Lec Hrs: 10

Introduction to solar PV systems – standalone PV system configuration – design methodology of PV systems – design of PV powered DC fan without battery, standalone system with DC load using MPPT, design of PV powered DC pump, design of standalone system with battery and AC/DC load – wire sizing in PV system – precise sizing of PV systems – Hybrid PV systems – grid connected PV systems.

UNIT - IV	**Wind Turbine Control Systems & Site Analysis**	**Lec Hrs: 12**
Wind Turbine - Torque speed characteristics - Pitch angle control – stall control – power electronic control – Yaw control – Control strategy – Wind speed measurements – Wind speed statistics – Site and turbine selection. Constant voltage & constant frequency- single output system –double output system with current converter & voltage source inverter – equivalent circuits – reactive power and harmonics - reactive power compensation – variable voltage, variable frequency – the self-excitation process – circuit model for the self-excited induction generator – analysis of steady state operation – the excitation requirement – effect of a wind generator on the network .		
UNIT - V	**Wind Generation With Variable Speed Turbines And Applications**	**Lec Hrs: 10**
Classification of schemes – operating area – induction generators – doubly fed induction generator – wound field synchronous generator – the permanent magnet generator – Merits and limitations of wind energy conversion systems – application in hybrid energy systems – diesel generator and photovoltaic systems – wind photovoltaic systems.		

Textbooks:

1. “Solar Photovoltaics Fundamentals, Technologies and Applications” by Chetan singh solanki, PHI publications.
2. S.N.Bhadra, D.Kastha, S.Banerjee, “ wind electrical systems” Oxford University Press

Reference Books:

1. Solar Energy Fundamentals and applications by H.P. Garg, J. Prakash “Tata McGraw- Hill publishers Ist edition”
2. S.Rao & B.B.Parulekar, “Energy Technology”, 4th edition, Khanna publishers, 2005.
3. “Renewable Energy sources & Conversion Technology” by N.K.Bansal, Manfred Kleemann,Michael Meliss. Tata Mcgraw Hill Publishers

Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22206	BIOMEDICAL MEASUREMENT SYSTEMS (21D22206) (PE-IV)	L	T	P	C
Semester	II		3	0	0	3

Course Objectives: Student will be able to

1. Understand the fundamental concepts of Bio-medical measurement system, Its modelling, various signals, signal processing, Imaging and Implantation
2. Apply the concepts & principles for the modelling 7 designing of various Biomedical systems
3. Analyze various Biomedical measurement systems by observing their characteristics
4. Create advanced Biomedical measurement systems with the help of imaging and implantation techniques

Course Outcomes (CO): After completion of the course Student may get knowledge to

1. Understand the fundamental concepts of Bio-medical measurement system, Its modelling, various signals, signal processing, Imaging and Implantation
2. Apply the concepts & principles for the modelling 7 designing of various Biomedical systems
3. Analyze various Biomedical measurement systems by observing their characteristics
4. Create advanced Biomedical measurement systems with the help of imaging and implantation techniques

UNIT - I	Biomedical Measurement System	Lec Hrs: 9

Physiological systems and measurable variables- Nature and complexities of biomedical measurements- Medical equipment standards- organization, classification and regulation- Biocompatibility - Human and Equipment safety — Physiological effects of electricity, Micro and macro shocks, thermal effects.

UNIT - II	Modelling & Analysis of Biomedical Systems	Lec Hrs: 10

Modelling and simulation in Biomedical instrumentation – Difference in modelling engineering systems and physiological systems — Model based analysis of Action Potentials - cardiacoutput – respiratory mechanism - Blood glucose regulation and neuromuscular function

UNIT - III	Biomedical Signals-Its Processing	Lec Hrs: 10

Types and Classification of biological signals – Signal transactions – Noise and artifacts and their management - Biopotential electrodes- types and characteristics - Origin, recording schemes and analysis of biomedical signals Electrocardiography(ECG) - with typical examples of and Electroencephalography(EEG) - Electromyography (EMG)– Processing and transformation of signals- applications of wavelet transforms in signal compression and denoising.

UNIT - IV	Medical Imaging	Lec Hrs: 9

Advanced medical imaging techniques and modalities -Instrumentation and applications in monitoring and diagnosis- Computed tomography - Magnetic Resonance Imaging and ultrasound- Algorithms and applications of artificial intelligence in medical image analysis and diagnosis- Telemedicine and its applications in tele monitoring.

UNIT - V	Implantable Biomedical Devices	Lec Hrs: 10

Implantable medical devices: artificial valves, vascular grafts and artificial joints- cochlear implants - cardiac pacemakers – Microfabriation technologies for biomedical Microsystems- microsensors for clinical applications – biomedical microfluid systems.

Textbooks:

1. John G.Webster, "Bioinstrumentation", John Wiley & Sons, 3rd Edition 2008.
2. Shayne C.Gad, "Safety Evaluation of Medical Devices", CRC Press, 2nd Edition, 2002.

Reference Books:

1. Michael C.K.Khoo, "Physiological Control Systems: Analysis, Simulation and Estimation, IEEE Press, 1st Edition 2000.
2. John G.Webster, "Medical Instrumentation Application and Design", John Wiley & Sons, 3rd Edition, 2009.
3. L.Cromwell, Fred J.Weibell and Erich A.Pfeiffer, "Biomedical Instrumentation and Measurements", Prentice Hall of India, Digitized 2010.
4. P.Strong, "Biophysical Measurements", Tektronix, Digitized 2007.
5. K.Najarian and R. Splinter, "Biomedical Signal and Image Processing", CRC Press, 1st Edition, 2012.
6. John L.Semmlow, "Biosignal and Biomedical Image Processing", CRC Press, 1st Edition, 2004.
7. Joseph J.Carr and John M.Brown, "Introduction to Biomedical Equipment Technology", Prentice Hall, 4th Edition, 2004.

Online Learning Resources:

R21 COURSE STRUCTURE & SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
(CONTROL SYSTEMS)

Course Code	21D22207	ROBUST CONTROL (21D22207) (PE-IV)	L	T	P	C
Semester	II		3	0	0	3

Course Objectives: Student will be able to

- To provide the students with the principles and tools of robust control theory: nominal stability, nominal performance, robustness, uncertainty, robust stability, loop shaping, H∞ control, robust performance.
- To familiarize the computational tools for control systems available in Robust Control Toolbox (MATLAB).
- To focus on an introduction to the fundamentals of robustness, uncertainty and design method of H∞ control.

Course Outcomes (CO): After completion of the course Student may get knowledge to

- Compute nominal stability and nominal performance.
- Explain robustness and uncertainty of systems.
- Acquire the fundamentals of H∞ control, and based on this knowledge, design multivariable feedback control systems.
- Understand robust performance.

UNIT - I	Review of Classical Feedback Control	Lec Hrs: 9

Review of classical feedback control: The control problem - Transfer functions - Deriving linear models - Frequency response - Feedback control - Closed loop stability - Evaluating closed - loop performance - Controller design - Loop shaping - Shaping closed loop transfer functions.

UNIT - II	Introduction to Multivariable Control	Lec Hrs: 10

Transfer functions for MIMO systems - Multivariable frequency response analysis - Control of multivariable plants - Introduction to robustness - General control problem formulation.

Elements of Linear System Theory: Internal stability of feedback systems - Stabilizing controllers - System norms - Input - Output Controllability - perfect control and plant inversion - Constraints on S and T.

UNIT - III	Limitations on Performance	Lec Hrs: 10

In SISO Systems: Limitations imposed by RHP - zeros - Limitations imposed by RHP - poles - Performance requirements imposed by disturbances and commands - Limitations imposed by input constraints - Limitations imposed by uncertainty.

In MIMO Systems: Constraints on S and T - Functional Controllability - Limitations imposed by RHP - zeros - Limitations imposed by RHP - poles - Performance requirements imposed by disturbances - Limitations imposed by input constraints - Limitations imposed by uncertainty.

UNIT - IV	Uncertainty and Robustness For SISO Systems	Lec Hrs: 9

Introduction to robustness - Representing uncertainty - parametric uncertainty - Representing uncertainty in the frequency domain - SISO robust stability - SISO robust performance - Examples of parametric uncertainty.

UNIT - V	Robust Stability, Performance Analysis and Control System Design	Lec Hrs: 10

General control formulation with uncertainty - Representing uncertainty - Obtaining P, N and M - Definition of robust stability and performance - Robust stability of the MΔ - structure - RS for complex unstructured uncertainty - RS with structured uncertainty: Motivation, The structured singular value and RS - Properties and computation of μ - Robust performance - Application: RP with input uncertainty - μ - synthesis and DK - iteration - Further remarks on μ - Trade - offs in MIMO feedback design - LQG control - H_2 and H_∞ control, H_∞ loop - shaping design.

Textbooks:

1. Sigurd Skogestad and Ian Postlethwaite, Multivariable Feedback Control Analysis and Design - John Wiley & Sons Ltd., 2nd Edition, 2005.
2. D. W. Gu, P. Hr. Petkov and M. M. Konstantinov "Robust Control Design with MATLAB" Spring - Verlag London Ltd., 2005.
3. K. Zhou and J. C. Doyle. Essentials of Robust Control. Prentice Hall; ISBN: 0-13-525833-2.

Reference Books:

1. Kennin Zhou, "Robust and Optimal Control", Prentice Hall, Engle wood Cliffs, New Jersy.
2. Robust Control Toolbox User's Guide R2017a. MathWorks.

Online Learning Resources:

Course Code	21D22208	PROCESS CONTROL LAB (21D22208)	L	T	P	C
Semester	II		0	0	4	2

Course Objectives: Student will be able to

1. Understand temperature pressure, flow control processes and study about PID controller, ratio control, feed forward control and cascade controller
2. Apply PID controllers to various control systems for finding open lop and closed loop responses
3. Analyze time domain specifications for different processes using above mentioned controllers

Course Outcomes (CO): After completion of the course Student may get knowledge to

1. Understand temperature pressure, flow control processes and study about PID controller, ratio control, feed forward control and cascade controller
2. Apply PID controllers to various control systems for finding open lop and closed loop responses
3. Analyze time domain specifications for different processes using above mentioned controllers

LIST OF EXPERIMENTS:

1) Study of Temperature control system:
   a) Open loop response
   b) Closed loop response with and without PID controller
2) Study of Pressure Control system:
   a) Open loop response
   b) Closed loop response with and without PID controller
3) Study of airflow control system:
   a) Open loop response
   b) Closed loop response with and without PID controller
4) Study of ratio control scheme for air flow process
5) Study of cascade control scheme for temperature process
6) Study of temperature control systems with and without feed forward controller
7) Study of liquid level control systems:
   a) Open loop response
   b) Closed loop response with and without PID controller
8) Study of liquid flow control systems:
   a) Open loop response
   b) Closed loop response with and without PID controller
9) Study of ratio control scheme for liquid flow process
10) Study of cascade control scheme for liquid level process
11) Study of liquid level control system with and without feed forward controller

Course Code	21D22209	ADVANCED CONTROL SYSTEMS SIMULATION LAB (21D22209)	L	T	P	C
Semester	II		0	0	4	2

Course Objectives: Student will be able to

1. Understand, Nonlinear systems & characteristics, Lyapunov function, linearization concepts, dynamic modelling and Riccatti equation
2. Apply Lyapunov function, Popov's stability and Isoclane methods for different systems
3. Analyze stability using Lyapunov function, Popov's stability and Isoclane methods and also to solve optimal control problem using Riccatti equation
4. Design smith predictor, LQG and LQR controllers

Course Outcomes (CO): After completion of the course Student may get knowledge to

1. Understand, Nonlinear systems & characteristics, Lyapunov function, linearization concepts, dynamic modelling and Riccatti equation
2. Apply Lyapunov function, Popov's stability and Isoclane methods for different systems
3. Analyze stability using Lyapunov function, Popov's stability and Isoclane methods and also to solve optimal control problem using Riccatti equation
4. Design smith predictor, LQG and LQR controllers

List of Experiments:

1. Identification of Non-Linear system characteristics
2. Nonlinear system stability analysis using Isoclines
3. Lyapunov function generation and stability test
4. Popov's stability criterion
5. Linearization of Non-linear models
6. Dynamic modelling of Continuous Stirred Tank Reactor
7. PID controller tuning for SISO systems
8. PID controller tuning for MIMO systems
9. Design of Smith predictor
10. Design of LQG controller
11. Design of Linear Quadratic Regulator
12. Solving Steady state Riccatti equation
13. Solving an optimal control problem using Riccatti equation

Course Code	21D22301	INDUSTRIAL DRIVES AND CONTROL (PE-V)	L	T	P	C
Semester	III		3	0	0	3

Course Objectives: Student will be able to

1. Understand torque, speed torque equations of electrical drives, classification of load torque, state space model of DC motor drive, principle of vector control and synchronous and special machines drives
2. Apply voltage, frequency and vector controller to control electric drives
3. Analyze DC motro, Induction motor, Synchronous motor and Special motor drives performance characteristics
4. Develop state models for half, semi, full and dual converter fed drives

Course Outcomes (CO): After completion of the course Student may get knowledge to

1. Understand torque, speed torque equations of electrical drives, classification of load torque, state space model of DC motor drive, principle of vector control and synchronous and special machines drives
2. Apply voltage, frequency and vector controller to control electric drives
3. Analyze DC motro, Induction motor, Synchronous motor and Special motor drives performance characteristics
4. Develop state models for half, semi, full and dual converter fed drives

UNIT - I DC MOTOR DRIVES **Lec Hrs: 10**

Electrical drives, Fundamental torque equations, Speed torque conventions and multi-quadrant operation, Components of load torques, Nature and classification of load torques, State space model of DC motor drive, Single-phase and Three-phase drives: Half converter, Semi converter, Full converter and Dual converter fed drives- Two quadrant and four quadrant chopper controlled drives – Closed loop control of DC drives

UNIT - II INDUCTION MOTOR DRIVES **Lec Hrs: 10**

Performance characteristics, Stator Control: Stator voltage control, Rotor voltage control, Frequency control, Voltage and frequency control, Current control, Voltage, current and frequency control - Rotor resistance control: Conventional methods, Static rotor resistance control - Slip power recovery: Static Kramer drive, Static Scherbius drive.

UNIT - III VECTOR CONTROL OF INDUCTION MOTOR DRIVES **Lec Hrs: 10**

Principle of vector control – Direct vector control - Flux vector estimation – Indirect vector control – Vector control of line-side PWM rectifier – Stator flux oriented vector control – Vector control of current fed inverter drive.

UNIT - IV SYNCHRONOUS DRIVES **Lec Hrs: 9**

Synchronous Motor Drives: Open loop volts/hertz control, Self control model, absolute position encoder, vector control and synchronous reluctance machine drives

UNIT - V SPECIAL DRIVES **Lec Hrs:9**

Permanent magnet ac motor drives, Brushless dc motor drives, Sensorless control - Stepper motor and Switched reluctance motor drives.

Textbooks:

1. Ion Boldea and Nasar S A, “Electric Drives”, CRC Press LLC, New York, 3rd Edition 2017.
2. Gopal K Dubey, “Fundamentals of Electric Drives”, Narosa Publishing House, New Delhi,

2016.

3. Bimal K. Bose "Modern Power Electronics and AC Drives" PHI 1st Edition 2002

Reference Books:

1. Muhammad H Rashid, "Power Electronics Handbook", Butterworth-Heinemann-Elsevier, 2014
2. Krishnan R, "Electric Motor Drives: Modelling, Analysis and Control", Prentice Hall of India, New Delhi, 2009.
3. Bimal K Bose, "Power Electronics and Variable Frequency Drives - Technology and Application", Standard Publishers Distributers, 2000.

Online Learning Resources:

Course Code	21D22302	DATA-DRIVEN CONTROL (PE-V)	L	T	P	C
Semester	III		3	0	0	3

Course Objectives: Student will be able to

1. Understand the concept of Iterative Feedback Tuning, Non-iterative direct data-driven tuning of multivariable controllers,;
2. Apply the concept of non-iterative Correlation- based Tuning, Willems' Fundamental Lemma.
3. Analyze the input-output data
4. Develop iterative learning control
5. Design control for parameter varying systems

Course Outcomes (CO): After completion of the course Student may get knowledge to

1. Understand the concept of Iterative Feedback Tuning, Non-iterative direct data-driven tuning of multivariable controllers, Direct data-driven control of linear parameter-varying and piece-wise affine systems.Model-free predictive control for hierarchical schemes.
2. Apply the concept of non-iterative Correlation- based Tuning, Willems' Fundamental Lemma., Learning-based Adaptive Control
3. Analyze the input-output data
4. Develop iterative learning control,virtual reference feedback control
5. Design control for parameter varying systems

UNIT - I | Preface to Data Driven Control | Lec Hrs: 9

Limitations of model-based control when the model is uncertain -Joint design of identification and control Taxonomy.

UNIT - II | Iterative Feedback Tuning | Lec Hrs: 10

Iterative Feedback Tuning, Virtual Reference Feedback Tuning, non-iterative Correlation- based Tuning. VRFT design for stable, integrating and unstable processes. Selection of reference models and their impact. Advantages and limitations direct data-driven control over traditional model-based design.

UNIT - III | Non Iterative feedback Tuning | Lec Hrs: 10

Non-iterative direct data-driven tuning of multivariable controllers-PID controller design directly based on data. Advantages and limitations.

UNIT - IV | Nonparametric Control | Lec Hrs: 9

Nonparametric control design and regularization. Optimal experiment design. The receding horizon approach. Data-driven selection of control specifications

UNIT - V | Direct Data Driven Control | Lec Hrs: 10

Direct data-driven control of linear parameter-varying and piece-wise affine systems. Model-free predictive control for hierarchical schemes. Willems' Fundamental Lemma.Learning-based Adaptive Control: An Extremum Seeking Approach. Model free adaptive control for SISO and MIMO nonlinear systems.

Textbooks:

1. Zhongsheng Hou, ShangtaiJin Model Free Adaptive Control: Theory and Applications, , CRC Press, 1st Edition 2014.

2. Learning-based Adaptive Control: An Extremum Seeking Approach, Mouhacine Benosman Butterworth-Heinemann, 1st 2016.
Reference Books:
1. S. Formentin, S. M. Savaresi, L. Del Noniterative direct data-driven tuning of multivariable controllers: theory and application, Re. IET control theory and applications, 2012; 6(9): 1250-1257. 2. K. van Heusden, A. Karimi, T. Söderström. On identification methods for direct data-driven controller tuning, International Journal of Adaptive Control and Signal Processing, 2011; 25(5): 448–465 3. M. Gevers,Identification for control: From the early achievements to the revival of experimentdesign, European journal of control, 2005; 11(4): 335-352. 4. M.C. Campi, A. Lecchini, S.M. Savaresi. Automatica "Virtual reference feedback tuning: a direct method for the design of feedback controllers" 1st Edition 2002;
Online Learning Resources:

Course Code	21D22303	GUIDANCE STRATEGIES FOR AUTONOMOUS VEHICLES (PE-V)	L	T	P	C
Semester	III		3	0	0	3

Course Objectives: Student will be able to

1. Understand the fundamental concepts of missile guidance and unmanned aircraft systems
2. Apply the cooperative control, feedback control procedures for missile guidance and UAS
3. Analyze missile guidance system with the help of cooperative control &UAS with classical and state space control
4. Design different control strategies(cooperative control, feedback control, classical and modern control) for missile guidance and UAS

Course Outcomes (CO): After completion of the course Student may get knowledge to

1. Understand the fundamental concepts of missile guidance and unmanned aircraft systems
2. Apply the cooperative control, feedback control procedures for missile guidance and UAS
3. Analyze missile guidance system with the help of cooperative control &UAS with classical and state space control
4. Design different control strategies(cooperative control, feedback control, classical and modern control) for missile guidance and UAS

UNIT - I	Overview of Missile Guidance	Lec Hrs: 9

Basics of missile guidance - Introduction to missiles, missile guidance laws (pursuit, line-of- sight, proportional navigation), capturability analysis form aneuvering and non-maneuvering targets

UNIT - II	Cooperative Control	Lec Hrs: 10

Applications of guidance strategies to cooperative control - multi-vehicle path planning, collision avoidance, rendezvous/docking problems.

UNIT - III	Unmanned Aircraft Systems	Lec Hrs: 10

Introduction to the unmanned aircraft systems (UAS). UAS design parameters, UAS components: mechanical & electrical, Overview of UAS Guidance & Navigation.

UNIT - IV	Dynamics of UAS	Lec Hrs: 9

Overview of dynamics of motion, Mechanics of flight (performance requirements, forces/moments, dynamics), UAS feedback control system characteristics, UAS control system stability and performance

UNIT - V	Controller Design for UAS	Lec Hrs: 10

Frequency response methods for UAS Flight Control Design,Classical and state space control design for UAS.

Textbooks:

1. Missile guidance and pursuit: Kinematics, Dynamics and Control, N.A.Shneydor: Harwood Publishing, 1st Edition 1998
2. Formation Control of Multiple Autonomous Vehicle Systems, Hugh H.T. Liu, Bo Zhu,Wiley, 1st Edition 2018.
3. Aircraft Control and Simulation, Brian L. Stevens, Frank L. Lewis, Eric N. Johnson,Third Edition, Wiley, 1st Edition, 2016.

Reference Books:

1. Autonomous Guided Vehicles: Methods and Models for Optimal Path Planning, Hamed

Fazlollahtabar, Mohammad Saidi-Mehrabad, Springer, 1st Edition 2015.

2. Autonomous Control Systems and Vehicles: Intelligent Unmanned Systems, Kenzo Nonami, Muljowidodo Kartidjo, Kwang-Joon Yoon, Agus Budiyono, Springer, 1st Edition 2013.
3. Multilayer Control of Networked Cyber-Physical Systems Application to Monitoring, Autonomous and Robot Systems, Sabato Manfredi, Springer, 1st Edition 2017.

Online Learning Resources:

Course Code	21D20301	WASTE TO ENERGY (Open Elective)	L	T	P	C
Semester	III		3	0	0	3

Course Objectives: To make the student

- To understand the concept of waste to energy.
- To analyze technical and management principles for production of energy from waste.
- To apply the best available technologies for waste to energy.
- To develop the process for thermal conversion, bio-chemical and waste to energy conversion.

Course Outcomes (CO): Student will be able to

CO 1: Understand the concept of waste to energy.
CO 2: Analyze technical and management principles for production of energy from waste.
CO 3: Apply the best available technologies for waste to energy.
CO 4: Develop the process for thermal conversion, bio-chemical and waste to energy conversion.

UNIT – I **Introduction to Energy from Waste** **Lecture Hrs: 9**

Classification of waste as fuel – Agro based – Forest residue – Industrial waste– MSW– Conversion devices–Incinerators – Gasifiers – Digestors.

UNIT - II **Biomass Pyrolysis** **Lecture Hrs: 9**

Pyrolysis – Types – Slow fast – Manufacture of charcoal – Methods – Yields and application– Manufacture of pyro lytic oils and gases – Yields and applications.

UNIT - III **Biomass Gasification** **Lecture Hrs: 10**

Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

UNIT - IV **Biomass Combustion** **Lecture Hrs: 10**

Biomass stoves – Improved challahs – Types, Some exotic designs – Fixed bed combustors– Types – Inclined grate combustors – Fluidized bed combustors – Design – Construction and operation– Operation of all the above biomass combustors.

UNIT - V **Introduction to Biogas** **Lecture Hrs: 10**

Properties of biogas (Calorific value and composition)–Biogas plant technology and status – Bio energy system–Design and constructional features–Biomass resources and their classification–Biomass conversion processes–Thermochemical conversion– Direct combustion–Biomass gasification– Pyrolysis and liquefaction– Biochemical conversion– an aerobic digestion Types of biogas Plants–Applications–Alcohol production from biomass– Biodiesel production–Urban waste to energy conversion – Biomass energy programme in India.

Textbooks:

1. Non-Conventional Energy, Desai, Ashok V.,WileyEasternLtd., 1st Edition,1990.
2. Biogas Technology– A Practical Hand Book- Khandelwal,K.C. and Mahdi, S.S.,Vol. I & II, Tata McGraw Hill Publishing Co.Ltd., 1st Edition,1983.

Reference Books:

1. Food, Feed and Fuel from Biomass, Challal, D.S., IBH Publishing Co. Pvt. Ltd., 1st Edition, 1991.
2. Biomass Conversion and Technology, C.Y. WereKo-Brobby and E.B.Hagan, John Wiley & Sons, 1st Edition, 1996.

Online Learning Resources:

1. https://www.digimat.in/nptel/courses/video/103107125/L01.html
2. https://nptel.ac.in/courses/103/107/103107125/