M.Tech. – Process Control & Instrumentation

Curriculum and Syllabus

Operative for the students admitted in 2013 and onwards

M.Tech. PROCESS CONTROL & INSTRUMENTATION

Course Structure and Scheme of Evaluation (Semester – wise)

[The total minimum number of credits = 64]

Code MPC	**Name of the Subject**	**Hours / week**			**Credit**
		L	**T**	**P**	
SEMESTER I					
CL 651	Instrumentation	3	0	0	3
CL 653	Chemical Process Systems				
CL 655	Modern Control Systems	3	0	0	3
CL 601	Advanced Process Control	2	1	0	3
	Elective I	3	0	0	3
	Elective II	3	0	0	3
	Elective III	3	0	0	3
CL 659	Process Control & Instrumentation Lab	0	0	3	2
Total number of credits in Semester I					**20**
SEMESTER II					
CL 652	Computational Techniques in Control Engineering	3	0	0	3
CL 654	Industrial Communication Systems	3	0	0	3
CL 656	System Identification	3	0	0	3
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
	Elective VI	3	0	0	3
CL 698	Lecture series	0	0	3	2
Total number of credits in Semester II					**20**
SEMESTER III					
CL 697	Project Work				12
Total number of credits in Semester – III					**12**
SEMESTER IV					
CL 798	Project Work				12
Total number of credits in Semester – IV					**12**
Total Credits in the Course					**64**

M.Tech. Degree
(Process Control and Instrumentation)

List of Core Subjects:

SEMESTER - I		
S.No.	**Code No.**	**Title**
1	CL 651	Chemical Process Systems
2	CL 653	Instrumentation
3.	CL 655	Modern Control Systems
4.	CL 601	Advanced Process Control
SEMESTER - II		
4.	CL 652	Computational Techniques In Control Engineering
5.	CL 654	Industrial Communication Systems
6.	CL 656	System Identification

List of Elective Subjects:

S.No.	Code No.	Title
1	CL 660	Digital Self tuning Control
2	CL 661	Computer Control of Processes
3	CL 662	Process Dynamics
4	CL 663	Instrumentation for Environmental Analysis
5	CL 664	Chemical Process Flow sheeting
6	CL 665	Computer Networks
7	CL 666	Soft computing techniques
8	CL 667	Control system design for process applications
9	CL 668	Safety in Process Industries
10	CL 669	Piping and Instrumentation Diagram
11	CL 670	Adaptive Control
12	CL 671	Probability and Computing
13	CL 672	Distillation Control
14	CL 673	Logic and Distributed Control System
15	CL 674	Digital Control System Design
16	CL 675	Real Time and Embedded Systems
17	CL 676	Micro-Electro-Mechanical Systems
18	CL 677	Industrial Measurements
19	CL 678	Optimal Control Theory
20	CL 679	Multi Sensor Data Fusion
21	CL 680	Non-linear Control Systems
22	CL 681	Physiological Control Systems
23	CL 682	Advanced Applied Process Control
		Any PG Elective from other Department

Syllabus for Each Subject from Next Page onwards

CL 651 CHEMICAL PROCESS SYSTEMS

OBJECTIVE:

To provide basic concepts of chemical engineering unit operations and processes

OUTCOME:

Understanding about basic concept, material balance and energy balance for analysis of unit processes and unit operations which is useful for the design the proper control system for process industries.

Historical overview of Chemical Engineering: Concepts of unit operations and unit processes, and more recent developments,. The Chemical Industry-scope, features & characteristics. and scope. Flow sheets, and symbols for various operations.

Material balances in simple systems involving physical changes and chemical reactions; systems involving recycle, purge. and bypass. combustion reactions, Forms of energy, optimum utilization of energy, Energy balance calculations in simple systems. Introduction to Computer aided calculations-steady state material and energy balances, combustion reactions.

Basic Fluid Concepts: Dimensions and Units, Velocity and Stress Fields, Viscosity and surface tension, Non Newtonian viscosity, Dimensional Analysis (Buckingham PI theorem), Types of flows, Methods of Analysis, Fluid Statics. pipe flow, Pumps, Agitation and Mixing, Compressors.

Review of conduction, resistance concept, extended surfaces, lumped capacitance; Introduction to Convection, natural and forced convection, correlations; Radiation; Heat exchangers-Fundamental principles and classification of heat exchangers, Evaporators

Fundamental principles and classification of Distillations, Adsorption, Absorption, Drying, Extraction, Membrane Process. Energy and Mass Conservation in process systems and industries. Introduction to chemical reactors.

TEXT BOOKS:

1. *G.T. Austin, R.N. Shreve, Chemical Process Industries, 5th ed., McGraw Hill, 1984.*
2. *W.L. McCabe, J.C. Smith and P. Harriott, "Unit Operations of Chemical Engineering", Sixth Edition, McGraw Hill, 2001.*
3. *R. M. Felder and R.W. Rousseau, Elementary Principles of Chemical Processes, 3rd ed., John Wiley, New York,2004.*
4. *L.B. Anderson and L.A. Wenzel, "Introduction to Chemical Engineering", McGraw Hill, 1961.*
5. *Fogler H.S., "Elements of Chemical Reaction Engineering", 4th Ed., Prentice-Hall, 2006.*

CL 653 INSTRUMENTATION

Objectives:

Outcome:

General concepts and terminology of measurement systems, static and dynamic characteristics, errors, standards and calibration.

Introduction, principle, construction and design of various active and passive transducers. Introduction to semiconductor sensors and its applications.

Design of signal conditioning circuits for various Resistive, Capacitive and Inductive transducers and piezoelectric transducer.

Introduction to transmitters, two wire and four wire transmitters, Smart and intelligent Transmitters. Design of transmitters.

Introduction to EMC, interference coupling mechanism, basics of circuit layout and grounding, concept of interfaces, filtering and shielding.
Safety: Introduction, electrical hazards, hazardous areas and classification, non-hazardous areas, enclosures – NEMA types, fuses and circuit breakers. Protection methods: Purging, explosion proofing and intrinsic safety.

TEXT BOOKS:

1. *John P. Bentley, Principles of Measurement Systems, Third edition, Addison Wesley Longman Ltd., UK, 2000.*
2. *Doebelin E.O, Measurement Systems - Application and Design, Fourth edition, McGraw-Hill International Edition, New York, 1992.*

REFERENCES:

1. *M. Sze, "Semiconductor sensors", John Wiley & Sons Inc., Singapore, 1994.*
2. *Noltingk B.E., "Instrumentation Reference Book", 2nd Edition, Butterworth Heinemann, 1995.*
3. *L.D.Goettsche, "Maintenance of Instruments and Systems – Practical guides for measurements and control", ISA, 1995.*
4. *Radhakrishnan,*

CL 655 MODERN CONTROL SYSTEMS

Objectives: The objective of this course is to expose students to the methods of control engineering that emerged in the field during the past 5 decades. As the industry is geared towards adopting these methods to build large scale and complex systems, this course prepares the student to take up such challenges in his profession.

Outcome: Upon completing the course, the student should have understood upward scaling of control engineering problems with a bent towards extensively utilizing the digital computer.

System Models
Examples, Building blocks of state space models, Canonical forms, State equation and its solution, Properties of the state transition matrix, Special cases, Modelling Discrete-time systems with delay operators.

Numerical Computations
Basic linear algebra, Eigenvalues and Eigenvectors, Similarity transformation, Gram-Schmidt Orthonormalization, Computing the matrix exponential using different algorithms, State transition matrix for discrete-time systems, Computational complexity.

Stability
Modelling energy of the system in terms of quadratic functions, Lyapunov's criterion for continuous- and discrete-time systems, Numerical methods for solving the Lyapunov equation, Computational complexity.

Controllability & Observability
Definitions, Rank tests, Computational methods of determining rank, Computational complexity, Lyapunov equation and Grammians.

Design in State Space
State feedback control for controllable canonical form, State feedback control in general, State feedback for discrete-time systems, Computational algorithms and their complexity, Output feedback control. Full-order and reduced-order observers, Physical aspects of control system design in state space.

TEXT BOOKS/REFERENCES

1. *Ramakalyan, A., Control Engineering: A Comprehensive Foundation, Vikas Publishing House, New Delhi, 2003.*
2. *Ogata, K., Discrete-Time Control Systems, 2/e, Prentice Hall of India.*
3. *Datta, B.N., Numerical Methods for Linear Control Systems, Elsevier, 2004. (A cheaper Indian reprint is available)*

CL 601 ADVANCED PROCESS CONTROL

OBJECTIVE:

Expose students to the advanced control methods used in industries and research. This course prepares the student to take up such challenges in his profession.

OUTCOMES:

Upon completing the course, the student should have understood

- controller tuning
- type of controller that can be used for specific problems in chemical industry
- design of controllers for interacting multivariable systems
- design of digital control systems

Review of Systems: Review of first and higher order systems, closed and open loop response. Response to step, impulse and sinusoidal disturbances. Transient response. Block diagrams.

Stability Analysis: Frequency response, design of control system, controller tuning and process identification. Zigler-Nichols and Cohen-Coon tuning methods, Bode and Nyquist stability criterion. Process identification.

Special Control Techniques: Advanced control techniques, cascade, ratio, feed forward, adaptive control, Smith predictor, internal model control.

Multivariable Control Analysis: Introduction to state-space methods, , Control degrees of freedom analysis and analysis, Interaction, Bristol arrays, Niederlinski index - design of controllers, Tuning of multivariable controllers.

Sample Data Controllers: Basic review of Z transforms, Response of discrete systems to various inputs. Open and closed loop response to step, impulse and sinusoidal inputs, closed loop response of discrete systems. Design of digital controllers. Introduction to PLC and DCS.

TEXT BOOKS:

1. *D.R. Coughanour, 'Process Systems analysis and Control', McGraw-Hill, 2nd Edition, 1991.*
2. *D.E. Seborg, T.F. Edger, and D.A. Millichamp, 'Process Dynamics and Control', John Wiley and Sons, 2nd Edition, 2004.*

***REFERENCES*:**

1 *B.A.Ogunnaike and W.H.Ray, "Process Dynamics, Modelling and Control", Oxford Press, 1994.*

2 *W.L.Luyben, 'Process Modelling Simulation and Control for Chemical Engineers', McGraw Hill, 2nd Edition, 1990.*

3 *B.W. Bequette, 'Process Control: Modeling, Design and Simulation', PHI, 2006.*

4 *S. Bhanot, 'Process Control: Principles and Applications', Oxford University Press, 2008.*

CL 659 PROCESS CONTROL & INSTRUMENTATION LAB

OBJECTIVES:

This laboratory aims at demonstrating every bit of mathematics taught in the theory course. Unlike several other laboratories, this course gives freedom to the student to work with a plant of his choice.

OUTCOME:

After completing this laboratory the student should have equipped himself with the skill of translating mathematical ideas to physical systems.

CL 652 COMPUTATIONAL TECHNIQUES IN CONTROL ENGINEERING

Objectives:
This course is an adaptation of numerical methods pertaining to control engineering problems. The algorithms are set in a numerical algebraic framework and are designed and analyzed in a formal way.

Outcome:
Upon completing this course, the student would be competent enough to develop software exclusively for control theoretic problems.

Review of Linear Algebra – Vector spaces, Orthogonality, Matrices, Vector and Matrix Norms, Kronecker Product

Numerical Linear Algebra – Floating point numbers and errors in computations, Conditioning, Efficiency, Stability, and Accuracy, LU Factorization, Numerical solution of the Linear system Ax = b, QR factorization, Orthogonal projections, Least Squares problem, Singular Value Decomposition, Canonical forms obtained via orthogonal transformations.

Control Systems Analysis – Linear State-space models and solutions of the state equations, Controllability, Observability, Stability, Inertia, and Robust Stability, Numerical solutions and conditioning of Lyapunov and Sylvester equations.

Control Systems Design – Feedback stabilization, Eigenvalue assignment, Optimal Control, Quadratic optimization problems, Algebraic Riccati equations, Numerical methods and conditioning, State estimation and Kalman filter.

Large scale Matrix computations, Some Selected Software – MATLAB, MATHEMATICA, SCILAB.

TEXTBOOKS/REFERENCES/RESOURCES:

1. B.N. Datta, *Numerical Methods for Linear Control Systems*, Academic Press/Elsevier, 2005 (Low cost Indian edition available including CD ROM).
2. G.H. Golub & C.F. Van Loan, *Matrix Computations*, 4/e, John Hopkins University Press, 2007 (Low cost Indian edition available from Hindustan Book Agency)
3. A. Quarteroni, F. Saleri, *Scientific Computing with MATLAB*, Springer Verlag, 2003.
4. www.scilab.org/download/

CL 654 INDUSTRIAL COMMUNICATION SYSTEMS

Objectives:
The objective of this course is to expose students to Communication systems emerged in the field. As the industry is progressing towards adopting these methods to build large scale Automation systems, this course prepares the student to take up such challenges in his Industrial Environment.

Outcome:
Upon completing the course, the student should have understood the concepts required for building industrial systems.

Interface: Introduction, Principles of interface, serial interface and its standards.
Parallel interfaces and buses.

Fieldbus: Use of fieldbuses in industrial plants, functions, international standards, performance, use of Ethernet networks, fieldbus advantages and disadvantages. Fieldbus design, installation, economics and documentation.

Instrumentation network design and upgrade: Instrumentation design goals, cost optimal and accurate sensor networks. Global system architectures, advantages and limitations of open networks, HART network and Foundation fieldbus network.

PROFIBUS-PA: Basics, architecture, model, network design and system configuration. Designing PROFIBUS-PA and Foundation Fieldbus segments: general considerations, network design.

TEXT BOOKS/REFERENCES

1. *Noltingk B.E., "Instrumentation Reference Book", 2nd Edition, Butterworth Heinemann, 1995.*
2. *B.G. Liptak, Process software and digital networks, 3rd Edition, CRC press, Florida.*

CL 656 SYSTEM IDENTIFICATION

Objectives:

The objective of this course is to expose students to different system identification concepts.

Outcome:

Upon completing the course, the student should have understood

- The concepts required for development of mathematical models for industrial systems.
- Development of models from first principles.
- Development of data driven models.

Introduction to system identification: identification based on differential equations, Laplace transforms, frequency responses, difference equations. Signals and system concepts, stationarity, auto-correlation, cross-correlation, power spectra. Random and deterministic signals for system identification: pulse, step, pseudo random binary sequence (PRBS).

Nonparametric model estimation: Correlation and spectral analysis for non-parametric model identification, obtaining estimates of the plant impulse, step and frequency responses from identification data.

Prediction-Error Model Structures: parametric estimation using one-step ahead prediction error model structures and estimation techniques for ARX, ARMAX, Box-Jenkins, FIR, Output Error models. Residual analysis for determining adequacy of the estimated models.

Introduction to nonlinear system identification: Similarities and differences from linear system identification, Development of nonlinear black-box models - Volterra, NARX, NARMAX, Wiener, Hammerstein.

Closed-Loop Identification: nonparametric closed-loop identification via correlation and spectral analysis. Identification with closed-loop data using indirect and direct approaches. Introduction to relay based identification.

Case studies using MATLAB/System Identification toolbox.

TEXT BOOKS:

Nelles, O. Nonlinear System Identification, Springer-Verlag, Berlin, 2001, ISBN: 3-54067369-5.

Karel J. Keesman, “System Identification, an introduction”, Springer, 2011.

Ljung, L. System Identification: Theory for the User, 2nd Edition, Prentice-Hall, 1999, ISBN 0-13-656695-2.

REFERNCES:

Kannan Moudgalya, Digital control, Wiley, 2007

Zhu, Y. Multivariable System Identification for Process Control, Pergamon, 2001, ISBN: 0-08-043985-3.

B.A. Ogunnaike and W.H. Ray, Process Dynamics, Modeling, and Control, Oxford University Press, ISBN 0-19-1994, 509119-1.

CL 660 DIGITAL SELF TUNING CONTROL

OBJECTIVES:

To give an overview of various methods of digital self tuning control methodologies for control of different processes. The focus shall be on the techniques themselves, rather than specific applications so that the student can take up modeling and simulation challenges in their profession.

OUTCOMES:

Upon completing the course, the student should have understood

- Adaptive control techniques
- Identification for the use in self-tuning controllers
- Self-tuning PID controllers
- How to use simulation tools such as MATLAB/SCILAB

Intoduction to adaptive control- formulation, design on heuristic approach. Model reference adaptive controllers, self tuning controllers.

System identification for self tuning controllers- stochastic process models. Identification algorithms- least squares, recursive least squares based methods.

Self- tuning PID controllers, nonlinear PID controllers, controllers for operational use. Algebraic methods foe self tuning controllers design- Dead- beat methods, pole assignment methods, Linear Quadratic methods.

Self tuning linear quadratic controllers- principle, optimization approach, stochastic approach, stability, tuning.

Solving problems using MATLAB/SCILAB.

TEXT BOOKS:

1. V.Bopal, J. Bohm, J.Fessel and J.Machacek. “Digital Self Tuning Controllers”, Springer,2005.
2. *Astrom .K, Adaptive Control, Second Edition, Pearson Education Asia Pte Ltd, 2002.*

CL 661 COMPUTER CONTROL OF PROCESSES

OBJECTIVES:
To impart knowledge on
Sampled data control system.
Various discrete control algorithms and parameter estimation methods.
Adaptive control algorithms

OUTCOMES:
Expose the students to the fundamentals of various digital control algorithms.

Computer control – Introduction – Review of Z Transform, Modified Z Transform and Delta Transform. Relation between Discrete and Continuous Transfer function-Poles and Zeros of Sampled Data System (SDS) – Stability Analysis in Z domain

Introduction to Pulse Transfer function- Open loop and closed loop response of SDS-Design and implementation of different digital control algorithm: Dead beat, Dahlin, Smith predictor and Internal Model Control algorithm with examples.

Different Models of Discrete System: LTI System:- Family of Discrete Transfer function Models- State Space models- Distributed Parameter Model. Models for Time varying and Non-linear System: Linear Time varying models- Non-linear State space models- Non-linear Black Box Models- Fuzzy Models

Parameter Estimation Methods: General Principles- Minimizing Prediction errors-Linear Regression and the Least Square method- Statistical Frame work for Parameter Estimation and the Maximum Likely hood method- Instrument Variable method – Recursive and Weighted Least square method

Adaptive Control: Introduction -Deterministic Self Tuning Regulator: Indirect and Direct self tuning regulator-Model reference Adaptive system: Design of MRAS using Lyapnov and MIT Rule- Auto tuning and Gain scheduling adaptive control design with examples.

TEXT BOOK:

1. *Lennart Ljung- System Identification Theory for the user – PTR Printice Hall Information and system sciences Series, NJ, 1999.*
2. *P. Deshponde and Ash, Computer Controlled System ISA Press, USA*
3. *Richard H. Middleton and Graham C. Goodwin 'Digital Control and Estimation A Unified Approach'Printice Hall NJ, 1990*
4. *Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp,' Process Dynamics and Control Willey India, 2006.*
5. *Astrom .K. J, Bjorn Wittenmark, Adaptive Control, Second Edition, Prentice Hall of India, New Delhi, 1994.*

CL 662 PROCESS DYNAMICS

OBJECTIVE:

Expose students to understand the nature of dynamics of chemical process elements and networks in process systems.

OUTCOMES:

Upon completing the course, the student should have understood

- nonlinear system behavior and tools for analysis
- dynamic behaviour and stability of chemical process control systems which involve momentum, heat and mass transfer operations

Basic equation - Integral and instantaneous balances - Material and Energy balances - General form of dynamic models. - Linearization of nonlinear systems in state space form - Response of lead-lag modules -Self-regulating system –transfer function analysis of higher order systems.

A second order system- Pole-Zero cancellation- System in series – Blocks in parallel- linear boundary value problems- Parameter estimation of discrete linear systems.

Phase-plane analysis- generalization of phase-plane behavior-nonlinear systems- Introduction to nonlinear dynamics-bifurcation behaviour of systems

Stirred tank heaters-Absorption-isothermal continuous stirred tank chemical reactors Biochemical reactors-adiabatic continuous stirred tank reactor-ideal binary distillation columns.

TEXT BOOKS:

1. *B.W. Bequette, " Process Dynamics – Modeling, Analysis and Simulation", PHIPE, New Delhi*
2. *G. Stephanopoulos, "Chemical process control: An Introduction to Theory and practice", Prentice Hall of India (P) Ltd., New Delhi, 1995.*

REFERENCE:

1. *F.G.Shinsky, "Process Control Systems: Application, Design and Adjustment", 3rd Edition, McGraw Hill Book Co., New York, 1988.*

CL 663 INSTRUMENTATION FOR ENVIRONMENTAL ANALYSIS

Objectives: To understand different instrumentation techniques for measurement of environmental parameters

Outcome: After completing the course, the students should be able to understand spectral methods, methods for water quality, air quality, sound and soil pollution.

Electromagnetic radiation, Characteristics - Interaction of e.m. radiation with matter - Spectral methods of analysis - absorption spectroscopy - Beer's law - radiation sources - monochromators and filters - diffraction grating - ultraviolet spectrometer - single beam and double beam instruments.

Particles emitted in radioactive decay - nuclear radiation detectors - injection chamber - Geiger - Muller counter - proportional counter - scintillation counter - Semiconductor detectors.

Measurement techniques for water quality parameters - conductivity - temperature - turbidity. Measurement techniques for chemical pollutants - chloride - sulphides - nitrates and nitrites - phosphates - fluoride - phenolic compounds.

Measurement techniques for particulate matter in air. Measurement of oxides of sulphur, oxides of nitrogen unburnt hydrocarbons, carbon-monoxide, dust mist and fog.

Noise pollution – measurement of sound, tollarable levels of sound. Measurement of sound level. Measurement techniques for soil pollution.

TEXT BOOKS:

1. H.H. Willard, Merrit and Dean, "Instrumental Methods of Analysis", 5th Edn., 1974.
2. R.K. Jain, "Fundamentals of Mechanical and Industrial Instrumentation", 1985.

REFERENCES:

1. S.P. Mahajan, "Pollution Control in Process Industries", Tata McGraw Hill, 1985.
2. G. N. Pandey and G.C. Carney, "Environmental Engineering", Tata McGraw-Hill, 1989.

CL 664 CHEMICAL PROCESS FLOW SHEETING

Pre Requisites: The students should have already learnt the chemical engineering fundamentals.

Objectives:

- The major objective is to understand how to invent chemical process flowsheets, how to generate and develop process alternatives, and how to evaluate and screen them quickly.
- To simulate the steady-state behavior of process flowsheets using a suitable simulation software.

Outcome:

At the conclusion of this course the successful student should be able to

- Understand the input/output structure of a flowsheet for a given manufacturing unit.
- Synthesize and design flowsheet sub-systems, to develop the recycle structure(s).
- Simulate the steady-state behavior of process flowsheets at each level of process development.

Course Content:

Flowsheeting

Introduction, Symbols, Flowsheet presentation with examples, Manual flowsheet calculation, Constrains and their applications in flowsheet calculations, Types of flow sheets, Synthesis of steady state flow sheet, Flowsheeting software.

Sequential modular approach to flowsheeting

Solution, partitioning and tearing a flowsheet, convergence of tear streams with suitable example.

Flowsheeting by equation solving methods

Selection, decision and tearing of variables in a flowsheet with simple and complex examples

Flowsheet applications

P & I D development, typical stages of P & I D, Applications of P & I D in design stage - Construction stage - Commissioning stage - Operating stage - Revamping stage - Applications of P & I D in HAZOPS and Risk analysis.

TEXT BOOKS:

1. *Ernest E. Ludwig, "Applied Process Design for Chemical and Petrochemical Plants", Vol.-I Gulf Publishing Company, Houston, 1989.*
2. *Max. S. Peters and K.D.Timmerhaus, "Plant Design and Economics for Chemical Engineers", McGraw Hill, Inc., New York, 1991.*

REFERENCES:

1. *Anil Kumar,"Chemical Process Synthesis and Engineering Design", Tata McGraw Hill publishing Company Limited, New Delhi - 1981.*
2. *A.N. Westerberg, et al., "Process Flowsheeting", Cambridge University Press, 1979.*
3. *Paul Benedek, "Steady state flow sheeting of Chemical Plants", Elsevier Scientific Publishing company.*

CL 665 COMPUTER NETWORKS

Computer communications architecture: Network topology; Switching: Circuit switching and packet switching; Datagrams and virtual circuits; ISO reference model for layered architecture; Functions of various layers.

Local area networks: Objectives and advantages of PC LANs; Topologies for LANs; Media for LANs; Medium access control techniques: CSMA, CSMA/CD, Token bus and token ring; Performance analysis for LANs.

Internetworking: Basic principles; Bridges and routers; Connection oriented and connectionless internetworking. Introduction to the protocols in the TCP/IP protocol suite.

ISDN and B – ISDN; Frame relay and asynchronous transfer mode (ATM). Data compression. Data security and authentication techniques.

Network management, Electrical mail, Network security, other internet applications. Test techniques for data networks: Basic tests; transmission impairment measurement tests; Time domain reflectometry (TDR). Line monitors and protocol analyzers.

TEXT BOOKS:

1. *Stalling W, Data and Computer Communications, Fifth edition, Prentice Hall of India, New Delhi, 1997.*
2. *William Stallings, High-speed Networks-TCP/IP and ATM Design Principles, Prentice Hall International Edition, New Jersey, 1998.*

REFERENCES:

1. *Ed Taylor, McGraw -Hill Internetworking Handbook, Second edition, McGraw Hill Company Inc., New York, 1998.*
2. *Bertsekas D and Gallager. R, Data Networks, Second edition, Prentice Hall of India, New Delhi, 1992.*

CL 667 CONTROL SYSTEM DESIGN FOR PROCESS APPLICATIONS

OBJECTIVES

The aim of this module is to introduce various techniques for the control of multivariable systems, recycle process.

Outcomes

- Expose the students to the fundamentals of multivariable control, recycle compensators, robust control.

Study of interaction analysis – Static RGA and dynamic RGA – Study of various decouplers- multivariable nyquist plot- Decentralized and centralized controllers. Multivariable pole placement -Case study –quadruple tank

Representation of various recycle process structures – Computation of the Recycle Effect Index – Recycle compensator design – Approximate dynamic models for recycle systems – Robust control system design for plants with recycle - Case study of two reactors in series

Representation of various inverse response structures – Inverse response compensators – Case study of gas chiller application – Inverse response compensation in TITO case.

LQR theory – RTDA concepts- Adaptive control theory – MRAC & STR based PID control design

Robustness analysis – Singular value analysis - Robust stability and Robust performance concepts

REFERENCES:

1. *Adaptive Control, K. J. Astrom and B. Wittenmark, Addison-Wesley, 1989.*
2. *Multivariable Feedback Control- Analysis and design, S. Skogestad and I. Postlethwaite. Wiley (1996; 2005)*
3. *Process Dynamics, Modeling and Control, Babatunde A. Ogunnaike and W. Harmon Ray(Nov 17, 1994)*
4. *P. Albertos and S. Antonio, " Multivariable Control Systems An Engineering Approach", Springer Verlag, 2004*
5. *Robust Process Control, M. Morari and E. Zafiriou, 1989*

CL 669 PIPING AND INSTRUMENTATION DIAGRAM

P&I Diagram objectives. Industry Codes and Standard. Government regulations

Engineering fluid diagrams. Electrical diagrams. Electronic diagrams. Logic diagrams.

DCS diagrams. Construction diagrams.

Format. Equipment. Instrumentation and Controls.

Application of P&I diagrams in HAZOPS and Risk analysis

Laboratory: Students are required to produce P&I Diagrams using software packages during the laboratory period of the course.

References:

Industry Codes and Standards
• American National Standards Institute (ANSI)
– ANSI/FCI 70-2-2003 – Control Valve Seat Leakage
• American Society of Mechanical Engineers (ASME)
– ASME Boiler and Pressure Vessel Code. Section VIII – Pressure Vessels
• The Instrumentation, Systems, and Automation Society (ISA)
– ISA 5.1 – Instrumentation Symbols and Identification
– ISA 5.2 – Binary Logic Diagrams for Process Operations
– ISA 5.3 – Graphic Symbols for Distributed Control / Shared Display Instrumentation, Logic and Computer Systems
– ISA 84.01 – Application of Safety Instrumented Systems for the Process Industries
• Tubular Exchanger Manufacturers Association (TEMA)
– TEMA Standards
Government Regulations
• Occupational Safety and Health Administration (OSHA)
– OSHA 29 CFR 1910.119 – Occupational Safety and Health Standards, Process Safety Management of Highly Hazardous Chemicals

CL 670 ADAPTIVE CONTROL

OBJECTIVE:

Expose students to the area of adaptive control.

OUTCOMES:

Upon completing the course, the student should have understood

- Various models used in system identification
- Parameter estimation algorithms and convergence
- Design of gain scheduling and self tuning control

System Identification: Introduction, dynamic systems, models, system identification procedure. Simulation and Prediction. Non-parametric time and frequency domain methods.

Linear dynamic system Identification: Overview, excitation signals, general model structure, time series models, models with output feedback, models without output feedback. Convergence and consistency.

Parameter estimation methods, minimizing prediction errors, linear regressions and Least squares method, Instrumental – variable method, prediction error method. Recursive algorithms. Closed-loop Identification.

Adaptive Control: Close loop and open loop adaptive control. Self-tuning controller. Auto tuning for PID controllers: Relay feedback, pattern recognition, correlation technique.

Adaptive Smith predictor control: Auto-tuning and self-tuning Smith predictor. Adaptive advanced control: Pole placement control, minimum variance control, generalized predictive control.

TEXT BOOKS:

1. *Ljung .L, System Identification: Theory for the user, Prentice Hall, Englewood Cliffs, 1987.*
2. *Astrom .K, Adaptive Control, Second Edition, Pearson Education Asia Pte Ltd, 2002.*

REFERENCES:

1. *Chang C. Hong, Tong H. Lee and Weng K. Ho, Adaptive Control, ISA press, Research Triangle Park, 1993.*
2. *Nelles. O, Nonlinear System Identification, Springer Verlag, Berlin, 2001.*

CL 671 PROBABILITY AND COMPUTING

OBJECTIVES:

Apart from obtaining good estimates of measured data, understanding stochastic processes, probability plays a major role in fast and high performance computations. The aim of the course is to demonstrate this facet of probability. In particular, the course explains ways in which computationally hard problems can be set in a stochastic framework.

OUTCOME:

Upon completing this course, the student is equipped with programming skills to solve large-scale and intractable problems that arise in the fields of instrumentation and control engineering.

Events and Probability: Verifying Polynomial Identities, Verifying Matrix Multiplication, A Randomized min-cut Algorithm.

Discrete Random Variables and Expectations: The Bernoulli and Binomial Random variables, Conditional Expectation, The Geometric Distribution, The Expected Run-time of Quick-Sort.

Moments and Deviations: Markov's Inequality, Variance and Moments of a Random Variable, Chebyshev's Inequality, A Randomized Algorithm for Computing the Median.

Chernoff Bounds: Moment Generating Functions, Deriving and Applying Chernoff Bounds, Better Bounds for Special cases.

Balls, Bins and Random Graphs: Poisson Distribution, Poisson Approximation, Hashing, Random Graphs

The Probabilistic Method: Basic Counting Argument, Expectation Argument, De randomization using Conditional Expectations, Sample and Modify, Second Moment Method, The Conditional Expectation Inequality, Lovasz Local Lemma.

Markov Chains and Random walks: Definition and Representations, Classification of States, Stationary Distributions, Random walks on undirected Graphs.

Continuous Distributions and The Poisson Process: Continuous Random variables, Uniform Distribution, Exponential Distribution, Poisson Process, Continuous Time Markov Processes, Markovian Queues.

Entropy, Randomness and Information: The Entropy Function, Entropy and Binomial Coefficients, A measure of Randomness, Compression

The Monte Carlo Method, The DNF Counting Problem, From Approximate Sampling to Approximate Counting, The Markov Chain Monte Carlo Method.

TEXTBOOK:

Mitzenmacher M, & Upfal E., Probability and Computing, Cambridge Univ. Press, 2005. (Cheaper Indian Edition is available)

CL 672 DISTILLATION CONTROL

OBJECTIVE:

- Expose students about the control of an energy intensive and an important unit operation in chemical engineering.

OUTCOMES:

Upon completing the course, the student should have understood

- Calculation of various parameters in distillation systems
- Importance of location of measurements
- The pairing and interaction in the multivariable control system
- The gain directions and use of it in control system design

Introduction to distillation operations - Binary separation concepts - McCabe - Thiele diagram - other parameters in binary distillation - Introduction to multicomponent separation - Minimum reflux - Number of plates calculations.

Classification of control schemes for distillation - Control of X_D and X_B upsets in F and X_F - Control of X_D and X_B for upsets in F and X_F - Choice of temperature measurement to infer composition.

Process identification - frequency response - Controller tuning. Dead time compensation - Smith and analytical predictors. Feed forward, cascade and Parallel Cascade control for distillation columns.

Dynamic modelling and simulation. Pairing and Interaction in distillation - Proper pairing in single and dual composition control- Relative Gain Analysis - Decoupling for non-interacting control.

Inferential Control Schemes for distillation. Model Algorithmic Control - DMC control strategy - comparison of MAC with classical feedback design. Adaptive control.

TEXT BOOKS:

1. *P.B. Deshpande, "Distillation Dynamics and Control", ISA, 1985*
2. *R.E.Treybal, "Mass Transfer Operations", Third Edn., McGraw Hill, 1993.*

REFERENCES:

1. *F.G. Shinskey, "Distillation Control", McGraw Hill, 1977.*
2. *P.S. Buckley, W.L.Luyben, P.S. Shunta and, "Design of Distillation Column Control Systems", ISA, 1985.*

CL 673 LOGIC AND DISTRIBUTED CONTROL SYSTEMS

Objectives:

Outcome:

Review of computers in process control: Data loggers, Data Acquisition Systems (DAS), Direct Digital Control (DDC). Supervisory Control and Data Acquisition Systems (SCADA), sampling considerations. Functional block diagram of computer control systems. alarms, interrupts. Characteristics of digital data, controller software, linearization. Digital controller modes: Error, proportional, derivative and composite controller modes.

Programmable logic controller (PLC) basics: Definition, overview of PLC systems, input/output modules, power supplies, isolators. General PLC programming procedures, programming on-off inputs/ outputs. Auxiliary commands and functions: PLC Basic Functions: Register basics, timer functions, counter functions.

PLC programming methods as per IEC 61131, Developing programs using Sequential Function Chart, Functional Block Diagram, Analog control using PLC (PID controller configuration), Interfacing PLC to SCADA/DCS using communication link (RS232, RS485) , Protocols (Modbus ASCII/RTU) and OPC, Development stages involved for PLC based automation systems.

Distributed Control System Basics: DCS introduction, Various function Blocks, DCS components/block diagram, DCS Architecture of different makes, comparison of these architectures with automation pyramid, DCS specification, latest trend and developments, DCS support to Enterprise Resources Planning (ERP), performance criteria for DCS and other automation tools.

Distributed Control Systems Engineering and Design: DCS detail Engineering, configuration and programming, functions including database management, reporting, alarm management, diagnosis, Historical database management, security and user access management, communication, third party interfaces ,control, display etc. Enhanced functions like Advance process control, fuzzy logic, ANN

Process safety and Safety Management Systems: Introduction to process safety, risk, risk terminologies, consequence and risk, risk measurement, Process Hazard Analysis (PHA), Hazard and operability study (HaZOp), Safety Integrity Level (SIL), Introduction to IEC61511 standard for Functional safety, protection layers, Safety Instrumented System: function, architecture, safety life cycle, Application of safety system

Practicals:

1. Preparing URS and FDS for any small automation project.
2. Prepare cause and effect document for any small process and also develop logic

diagram for the same.
3. Develop and implement any PLC and/or DCS program using FBD and SFC programming language.
4. Interfacing of PLC to any SCADA through Modbus protocol and/or OPC.
5. Interfacing of PLC to a DCS system through Modbus and/or OPC.
6. Developing and implementing any control loop using PLC system.
7. Developing and implementing any control loop using DCS system
8. Developing and configuring Graphic User Interface for any control loop.
9. Configuration of any HART device to PLC and/or DCS system.
10. Configuration of any Foundation Fieldbus device to PLC and /or DCS system.
11. Configure and implement different alarms in PLC and/or DCS system.
12. Configuring and implementing any Advance process control function like MPC/or Fuzzy/or ANN in a DCS system
13. Preparing a HaZOp document for any small process
14. Develop a G-code for any machining process.

TEXT BOOKS:

1. Understanding Distributed Process Systems For Control, Samuel Herb, ISA.
2. Programmable Logic Controllers: Principles and Applications, Webb &Reis, PHI.
3. Introduction to Programmable Logic Controllers, Garry Dunning, Thomson Learning.
4. Distributed computer control for industrial automation, Ppovik Bhatkar, Dekkar Pub.
5. Computer Based Process control, Krishna Kant, PHI

REFERENCES:

6. John. W.Webb Ronald A Reis , Programmable Logic Controllers - Principles and Applications, Third edition, Prentice Hall Inc., New Jersey, 1995.
7. Distributed Systems Concepts and Design, fourth edition George Coulouris, Jean Dollimore, Tim Kindberg
8. Computer Networks: A Systems Approach, fourth edition, by Larry Peterson and Bruce Davie.
9. Operating Systems Concepts seventh edition, by Silberschatz, Galvin and Gagne
10. Distributed Systems: Principles and Paradigms, by Tanenbaum and van Steen
11. Distributed Systems: Concepts and Design, fourth edition, by Coulouris, et al

CL 674 DIGITAL CONTROL SYSTEM DESIGN

Objectives:

Outcome:

Discrete time signals, Discrete time systems, Sampling and reconstruction, digitizing analog controllers.

Discrete time state equations, discrete time system response, the characteristic value problem, Uncoupling state equations, Observability and controllability.

Observability and state observation, Estimation and identification, Controllability and state control, State feedback, Output feedback.

Full order state observer, Observer design, Lower-order observers, Eigenvalue placement with observer feedback.

Ideal tracking system design, Response model tracking system design, Reference model tracking system design.

REFERENCES:

1. *Gene H. Hostetter, Digital Control System, Second Edition Holt,Rinehart and Winston, Inc.U.S, 1997.*
2. *Ogata K, Discrete Time Control Systems, Pearson Education, 2001.*
3. *Gopal M, Digital Control and State variable Methods, Second Edition, Tata McGrawHill, New Delhi, 2003.*

CL 675 REAL TIME AND EMBEDDED SYSTEMS

System Design: Definitions, Classifications and brief overview of micro-controllers, microprocessors and DSPs. Embedded processor architectural definitions. Typical application scenarios of embedded systems.

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

Techniques for Embedded Systems: 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.

Real time Models, Language and Operating Systems: Event based, process based and graph based models, Petrinet models – Real time languages – The real time kernel, OS tasks, task state4s, 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.

TEXT BOOK AND REFERENCES:

1. *Ball S.R, Embedded microprocessor systems – Real World Design, Prentice Hall, 1996.*
2. *Herma K, Real Time Systems – Design for Distributed Embedded Applications, Kluwer Academic, 1997.*
3. *Gassle J, Art of Programming Embedded Systems, Academic Press, 1992.*
4. *Gajski D.D, Vahid F, Narayan S, Specification and Design of Embedded Systems, PRT Prentice Hall, 1994.*
5. *Intel manual on 16-bit embedded controllers, Santa Clara, 1991.*
6. *Slater M, Microprocessor based design, a Comprehensive guide to effective hardware design, Prentice Hall, New Jersey, 1989.*
7. *Peatman, J.B, Design with Micro controllers, McGraw Hill International Ltd., Singapore, 1989.*
8. *C.M. Krishna, Kang G. Shin, Real Time Systems, McGraw Hill, 1997.*
9. ***Raymond J.A. Buhr, Donald L. Bailey, An Introduction to Real Time Systems, Prentice Hall International, 1999.***

CL 676 MICRO-ELECTRO-MECHANICAL SYSTEMS

Introduction, emergence, devices and application, scaling issues, materials for MEMS, Thin film deposition, lithography and etching.

Bulk micro machining***:*** Introduction, etch-stop techniques, dry etching, buried oxide process, silicon fusion bonding, and anodic bonding.
Surface micro machining***:*** Introduction, sacrificial layer technology, material systems in sacrificial layer technology, plasma etching, combined IC technology and anisotropic wet etching.

Microstereolithography: Introduction, Scanning Method, Projection Method, Applications. LIGA Process: Introduction, Basic Process and Application

MEMS devices, electronic interfaces, design, simulation and layout of MEMS devices using CAD tools.

TEXT BOOKS:

1. *S.M. Sze, Semiconductor Sensors, John Wiley & Sons, INC., 1994.*
2. *M.Elwenspoek, R.Wiegerink, Mechanical Microsensors, Springer-Verlag Berlin Heidelberg, 2001.*

REFERENCES:

1. *Massood Tabib-Azar, Microactuators - Electrical, Magnetic, Thermal, Optical, Mechanical, Chemical and Smart structures, Kluwer Academic Publishers, New York, 1997.*
2. *Eric Udd , Fiber Optic Smart Structures , John Wiley & Sons, New York, 1995.*

CL 678 OPTIMAL CONTROL THEORY

OBJECTIVES:

To impart knowledge on

- Dynamic Programming
- Calculus of variation
- Pontryagin's Minimum Principle
- Optimization techniques

OUTCOMES:

- Expose the students to the fundamentals of dynamic programming, calculus of variation and various optimization techniques.

Problem formulation – Mathematical model – Physical constraints - Performance measure Optimal control problem. Form of optimal control. Performance measures for optimal control problem. Selection a performance measure.

Dynamic Programming – Optimal control law – Principle of optimality. An optimal control system. A recurrence relation of dynamic programming – computational procedure. Characteristics of dynamic programming solution. Hamilton – Jacobi – Bellman equation. Continuous linear regulator problems.

Calculus of variations – Fundamental concepts. Functionals. Piecewise – smooth extremals Constrained extrema.

Variational approach to optimal control problems – Necessary conditions for optimal control – Linear regulator problems. Linear tracking problems. Pontryagin's minimum principle and state inequality constraints.

Minimum time problems – Minimum control – effort problems. Singular intervals in optimal control problems. Numerical determination of optimal trajectories – Two point boundary – valve problems. Methods of steepest decent, variation of extremals. Quasilinearization. Gradient projection algorithm.

TEXTBOOK:

1. *Donald E. Kirk, Optimal Control Theory: An Introduction, Prentice-Hall networks series, 1970.*

REFERENCES:

1. *Anderson .B. D. O, Moore .J. B, Optimal control linear Quadratic methods, Prentice Hall of India, New Delhi, 1991.*
2. *Sage A. P, White .C. C, Optimum Systems Control, Second Edition, Prentice Hall, 1977.*

CL 679 MULTI SENSOR DATA FUSION

Multisensor data fusion: Introduction, sensors and sensor data, Use of multiple sensors, Fusion applications. The inference hierarchy: output data. Data fusion model. Architectural concepts and issues. Benefits of data fusion, Mathematical tools used: Algorithms, co-ordinate transformations, rigid body motion. Dependability and Markov chains, Meta – heuristics.

Taxonomy of algorithms for multisensor data fusion. Data association. Identity declaration.

Estimation: Kalman filtering, practical aspects of Kalman filtering, extended Kalmal filters. Decision level identify fusion. Knowledge based approaches.

Data information filter, extended information filter. Decentralized and scalable decentralized estimation. Sensor fusion and approximate agreement. Optimal sensor fusion using range trees recursively. Distributed dynamic sensor fusion.

High performance data structures: Tessellated, trees, graphs and function. Representing ranges and uncertainty in data structures. Designing optimal sensor systems with in dependability bounds. Implementing data fusion system.

TEXT BOOKS:

1. David L. Hall, Mathematical techniques in Multisensor data fusion, Artech House, Boston, 1992.
2. R.R. Brooks and S.S. Iyengar, Multisensor Fusion: Fundamentals and Applications with Software, Prentice Hall Inc., New Jersey, 1998.

REFERENCES:

1. Arthur Gelb, Applied Optimal Estimation, The M.I.T. Press, 1982.
2. James V. Candy, Signal Processing: The Model Based Approach, McGraw – Hill Book Company, 1987.

CL 680 NON-LINEAR CONTROL SYSTEMS

OBJECTIVES:

The main goal of this course is to provide to the students a solid background in analysis and design of nonlinear control systems. This course provides an introduction to nonlinear deterministic dynamical systems, and applications to nonlinear circuits and control systems.

OUTCOME:

Upon successfully completing this course, the student should be able to appreciate that many control systems of practical importance are inherently nonlinear, and he should have been equipped with necessary analytical and computational tools to analyze nonlinear systems and design suitable controllers.

CL 682 ADVANCED APPLIED PROCESS CONTROL

Objectives: To understand how to apply advanced control concepts to different processes

Outcome: After completion of the course, the student should be able to understand how to identify processes and implement different control algorithms for efficient control.

Control relevant process modeling and identification: Model applications, types of models, empirical dynamic models, model structure considerations, model identification.

Identification examples: SISO furnace parametric model identification, MISO parametric model identification, MISO non-parametric identification of a non-integrating process, MIMO identification of an integrating and non-integrating process, design of plant experiments, conversion of model structures.

Linear multivariable control: Interaction in multivariable systems, Dynamic matrix control, properties of commercial MPC packages.

Multivariable optimal constraint control algorithm: Model formulation for systems with dead time, model formulation for multivariable processes with and without time delays, model formulation in case of a limited control horizon, Non-linear transformations.

Nonlinear multivariable control: Non-linear model predictive control, non-linear quadratic DMC, generic model control, GMC application to chemical engineering systems, one step reference trajectory control.

TEXT BOOKS/REFERENCES:

1. *B. Roffel, B.H.L. Betlem, "Advanced Practical Process Control" Springer, 2004.*
2. *Jean Pierre Corriou, "Process Control: Theory and applications" Springer, 2004.*
3. *C.A. Smith and A.B. Corrupio," Principles and Practice of Automotive Process Control", John Wiley, New York, 1976*