M. Tech. DEGREE

PROCESS CONTROL AND INSTRUMENTATION

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(2009 -2010)

DEPARTMENT OF CHEMICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015, INDIA.

M.Tech. PROCESS CONTROL & INSTRUMENTATION

[The total minimum number of credits = 62]

SEMESTER -1

Code	Course of Study	L	T	P	C
CL 651	Instrumentation	3	0	0	3
CL 653	Modern Control System	3	0	0	3
CL 655	Process Modeling and Simulation	3	0	0	3
CL 657	Advanced Process Control	3	1	0	4
	Elective I	3	0	0	3
	Elective II	3	0	0	3
CL 659	Process Control Laboratory	0	0	3	1
					20

SEMESTER -2

Code	Course of Study	L	T	P	C
CL 652	Computer Control of Process	3	0	0	3
CL 654	Industrial Communication Systems	3	0	0	3
CL 656	Chemical Process Flow sheeting	3	0	0	3
	Elective III	3	0	0	3
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
CL 698	Control & Instrumentation Lab	0	0	3	1
					19

SEMESTER-3

Code	Course of Study	L	T	P	C
CL 697	Project Work – Phase I	0	0	24	12

SEMESTER-4

Code	Course of Study	L	T	P	C
CL 698	Project Work – Phase II	0	0	24	12

Elective I & II:

Code	Course of Study	L	T	P	C
CL 661	Chemical Process Systems	3	0	0	3
CL 663	Process Dynamics	3	0	0	3
CL 665	Instrumentation for Environmental Analysis	3	0	0	3
PH 713	Digital Signal and Image Processing	3	0	0	3
	Any PG Elective from other Department	3	0	0	3

Elective III, IV & V

Code	Course of Study	L	T	P	C
CL 658	Distillation Control	3	0	0	3
CL 660	Bio process instrumentation and Control	3	0	0	3
CL 662	Fuzzy logic and Neural Networks	3	0	0	3
CL 664	Internet for measurement Control	3	0	0	3
IC 766	Micro Fluidics and Bio MEMS	3	0	0	3
IC 762	Design of Intelligent Controllers	3	0	0	3
	Any PG Elective from other Department	3	0	0	3

List of Reserved Electives

Code	Course of Study	L	T	P	C
CL 666	Logic and Distributed Control System	3	0	0	3
CL 667	Computer Networks	3	0	0	3
CL 668	Multi Sensor Data Fusion	3	0	0	3
CL 669	Optimal Control Theory	3	0	0	3
CL 670	Stochastic Processes and Estimation theory	3	0	0	3
CL 671	Bioprocess Engineering	3	0	0	3
CL 672	Control System Design	3	0	0	3
CL 673	Discrete Output Feedback Control	3	0	0	3
CL 674	System Identification	3	0	0	3
CL 675	Real Time and Embedded Systems	3	0	0	3
CL 676	Virtual Instrumentation	3	0	0	3
CL 677	Adaptive Control	3	0	0	3
CL 678	Microelectro-Mechanical Systems	3	0	0	3
CL 679	Advanced Applied Process Control	3	0	0	3
CL 680	Piping and Instrumentation	3	0	0	3

CL 651 INSTRUMENTATION

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.*

CL 653 MODERN CONTROL SYSTEM

Introduction to control systems, properties of signals and systems. Convolution integral, Ordinary differential equation, Transfer function, Pole zero concepts, effect of pole location on performance specification. System models in state space, canonical model, MIMO systems, solution of state equation, stability of systems in state space.

Linear algebra, vector spaces, span and change of basis, linear transformations. Gram Schmidt orthogonalization criterion, QR decomposition. Singular Ivalue decomposition.

Computing e^{AT} Controllability, Observability controller design, observer design, reduced order observers, properties of controllability. Computing numerical rank of a matrix. Kalman canonical forms, partial pole assignment using static pole output feedback. Design of non - interacting systems.

Non-linear system analysis: Non-linear system behaviour, different methods of linearization, Lyapnov stability criterion. Phase plane analysis, singular points, constructing phase portraits, existence of limit cycle.

Describing function analysis: Fundamentals, assumptions, definitions. Describing functions of common non-linearities. Describing function analysis of non-linear system. Stability of limit cycles, reliability of describing function analysis.

TEXT BOOKS

1. *Brogan W. L, Modern Control theory, Prentice Hall International, New Jersey, 1991.*
2. *Jean-Jacques E. Slotine, Weiping Li, Applied nonlinear control, Prentice Hall Inc., New Jersey, 1991.*

REFRENCES

1. *Skelton R. E, Dynamic System Control and Linear System Analysis and Synthesis, John Wiley and Sons Inc., New Delhi, 1993.*
2. *Vidyasagar .M, Nonlinear system analysis, Second Edition, Prentice Hall Inc., New Jersey, 1993*

CL 657 PROCESS MODELLING AND SIMULATION

Introduction to modelling, a systematic approach to model building, classification of models. Conservation principles, thermodynamic principles of process systems.

Development of steady state and dynamic lumped and distributed parameter models based on first principles. Analysis of ill-conditioned systems.

Development of grey box models. Empirical model building. Statistical model calibration and validation. Population balance models. Examples.

Solution strategies for lumped parameter models. Stiff differential equations. Solution methods for initial value and boundary value problems. Euler's method. R-K method, shooting method, finite difference methods. Solving the problems using *MATLAB/SCILAB*.

Solution strategies for distributed parameter models. Solving parabolic, elliptic and hyperbolic partial differential equations. Finite element and finite volume methods.

TEXT BOOKS

1. *K. M. Hangos and I. T. Cameron, "Process Modelling and Model Analysis", Academic Press, 2001.*
2. *W.L. Luyben, "Process Modelling, Simulation and Control for Chemical Engineers", 2nd Edn., McGraw Hill Book Co., New York, 1990.*
3. *W. F. Ramirez, "Computational Methods for Process Simulation", Butterworths, 1995.*

REFERENCES

1. *Mark E. Davis, "Numerical Methods and Modelling for Chemical Engineers", John Wiley & Sons, 1984.*
2. *Singiresu S. Rao, "Applied Numerical Methods for Engineers and Scientists" Prentice Hall, Upper Saddle River, NJ, 2001*

CL 652 COMPUTER CONTROL OF PROCESS

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 654 INDUSTRIAL COMMUNICATION 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 BOOK

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 655 ADVANCED PROCESS CONTROL

Review of systems: Review of first and higher order systems, closed and open loop response. Response to step, impulse and sinusoidal disturbances. Control valve types-linear, equal percentage and quick opening valve. Design of valves. 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-Nyquist Plots - Process modelling.

Special Control Techniques: Advanced control techniques, cascade, ratio, feed forward, adaptive control, selective controls, computing relays, simple alarms, Smith predictor, internal model control, theoretical analysis of complex processes.

Multivariable Control Analysis of multivariable systems, Interaction, examples of storage tanks. Review of matrix algebra, Bristol arrays, Niederlinski index - 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.

TEXT BOOKS

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

REFERENCES

1. *'Principle and Practice of Automatic Process Control', C.A.Smith and A.B.Corripio, John Wiley and Sons, 1985.*
2. *'Process Modelling Simulation and Control for Chemical Engineers', W.L.Luyben, McGraw Hill, II Edition, 1990.*
3. *'Chemical Process Control – Theory and Practice', Stephanopoulous, Prentice Hall of India Ltd.,.1984.*

CL 656 CHEMICAL PROCESS FLOWSHEETING

Flowsheeting

Introduction, Symbols, Flowsheet presentation with examples, Manual flowsheet calculation, Constrains and their applications in flowsheet calculations.

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

Flowsheeting on the computer
Motivation for development, Physical property service facilities – data cycle, computerized physical property systems and calculations, Degrees of freedom in a flowsheet – Independent stream variables, degrees of freedom analysis.

Applications of flowsheeting software – Case studies (for class work only)

TEXT BOOKS
1. Westerberg A.W. et al., "Process Flowsheeting", Cambride University Press, 1979.
2. Ernest E. Ludwig, "Applied Process Design for Chemical and Petrochemical Plants", VOl – I, Gulf Publishing Company, Houston, 1989.

REFERENCES
1. Anil Kumar, " Chemical Process synthesis and Engineering Design", Tata McGraw Hill publishing company Limited, New Delhi, 1981
2. Peters, Max. S. and Timmerhaus K.D, "Plant Design and Economics for Chemical Engineers", McGraw Hill, Inc., New York, 1991.

CL 658 DISTILLATION CONTROL

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. *W.L. MaCabe, J.C.Smith and P. Harriott, "Operations of Chemical Engineering", Fifth 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.*

ELECTIVE SUBJECTS

CL 661 CHEMICAL PROCESS SYSTEMS

Typical products and their and uses, Systematic analysis of chemical processes. Flow sheets and symbols for various operations. Variation in process conditions, raw materials and fuels – effect on end products and economy.

Overall Balances, Component balances in engineering equipment, combustion reactions, Stoichiometric balances in manufacturing processes.

Forms of energy, Total balance, Heat balance, Heat effects and combustion reactions, Energy balances in manufacturing processes, optimum utilization of energy, Heat transfer operations in chemical reactors. Equipments- Fundamental concepts in heat exchangers, Evaporators and distillation column, Design and classification of heat exchangers, Evaporators and distillation column.

Fundamental principles and classification of heat exchangers, Evaporators, Distillation columns and equipment for Agitation and mixing of fluids dimensional analysis to estimate power consumption for agitation.

Energy Conservation in process systems and industries, Optimization principles and pinch analysis to calculate energy consumption.

TEXT BOOKS

1. *W.L. McCabe, J.C. Smith and P. Harriott, "Unit Operations of Chemical Engineering", sixth Edition, McGraw Hill, 2001.*
2. *Walter L.Badger and Julivst. Banchero "Introduction to Chemical Engineering", Tata McGraw Hill publishing company, 1997*

REFERENCES

1. *L.B. Anderson and L.A. Wenzel, "Introduction to Chemical Engineering", McGraw Hill, 1961.*
2. *P.Harriot, "Process Control", McGraw Hill, 1984.*
3. *D.A. Reay, "Industrial Energy Conservation", McGraw-Hill, New York, 1979.*

CL 663 PROCESS DYNAMICS

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 665 INSTRUMENTATION FOR ENVIRONMENTAL ANALYSIS

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 660 BIOPROCESS INSTRUMENTATION & CONTROL

Physical and chemical sensors; Biosensors; On-line sensors for cell properties; off-line Analytical methods.

Agitation and capacity coefficient in fermenters; Control of pH, dissolved oxygen, dissolved carbon dioxide, temperature of fermenters; Rheological measurement and control application of microcomputers in the study of microbial process.

Elements of Digital computers; Computer Interfaces and peripheral devices; Fermentation software systems

Data smoothing and interpolation; State and parameter estimation; Direct regulatory control; cascade control of metabolism.

Programmed batch bio-reaction; Design and operation strategies for batch plants; Continuous process control.

TEXT BOOKS

1. *Bailey J.E. and Ollis,D.F. " Biochemical Engineering Fundamentals" 2nd Edition, (1986), McGraw Hill Book CO.,Singapore.*
2. *T.K.Ghose (Ed.) "Process Computations in Biotechnology" (1994), Tata McGraw Hill Publ.Co.,N.Delhi.*
3. *A.Fischer (Ed.), "Advances in Biochemical Engineering," Vol. 13, 1973, Springer Verlag, Germany*

REFERENCES

1. *Aiba, Humphry and Millis, "Bio Chemical Engineering", 2nd Ed., (1973), Academic press*
2. *McNeil and Harvey, "Fermentation - A Practical Approach" (1990). IRL Press, U.K.*
3. *Scragg, "Bioreactors in Biotechnology - A Practical Approach" (1991), Ellis Horwood Ltd., U.K.*

CL 662 FUZZY LOGIC, NEURAL NETWORKS AND CONTROL

Introduction to Neural Networks: Artificial Neural Networks: Basic properties of Neurons, Neuron Models, Feedforward networks – Perceptrons, widrow-Hoff LMS algorithm; Multilayer networks – Exact and approximate representation, Back propagation algorithm, variants of Back propagation, Unsupervised and Reinforcement learning; Symmetric Hopfield networks and Associative memory; Competitive learning and self organizing networks, Hybrid Learning; Computational complexity of ANNs.

Neural Networks Based Control: ANN based control: Introduction: Representation and identification, modeling the plant, control structures – supervised control, Model reference control, Internal model control, Predictive control: Examples – Inferential estimation of viscosity an chemical process, Auto – turning feedback control, industrial distillation tower.

Introduction to Fuzzy Logic: Fuzzy Controllers: Preliminaries – Fuzzy sets and Basic notions – Fuzzy relation calculations – Fuzzy members – Indices of Fuzziness – comparison of Fuzzy quantities – Methods of determination of membership functions.

Fuzzy Logic Based Control: Fuzzy Controllers: Preliminaries – Fuzzy sets in commercial products – basic construction of fuzzy controller – Analysis of static properties of fuzzy controller – Analysis of dynamic properties of fuzzy controller – simulation studies – case studies – fuzzy control for smart cars.

Neuro – Fuzzy and Fuzzy – Neural Controllers: Neuro – fuzzy systems: A unified approximate reasoning approach – Construction of role bases by self learning: System structure and learning algorithm – A hybrid neural network based Fuzzy controller with self learning teacher. Fuzzified CMAC and RBF network based self-learning controllers.

TEXT BOOKS

1. *Bose and Liang, Artificial Neural Networks, Tata Mcgraw Hill, 1996.*
2. *Kosco B, Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence, Prentice Hall of India, New Delhi, 1992.*

REFERENCES

1. *Klir G.J and Folger T.A, Fuzzy sets, Uncertainty and Information, Prentice Hall of India, New Delhi 1994.*
2. *Simon Haykin, Neural Networks, ISA, Research Triangle Park, 1995.*

CL 664 INTERNET FOR MEASUREMENT AND CONTROL

Introduction 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.

Network Layer Aspects and Network Security: 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.

Measurements through Internet: 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 controllers through Internet.

REFERENCES

1. *Douglas E. Camer, Internet working with TCP/IP, Vol. I, Third Edition, Prentice Hall, 1999.*
2. *Richard Stevens, TCP/IP illustrated, Vol. I, Addison Wesley, 1999.*
3. *Richard E. Smith, Internet Cryptography, Addison Wesley, 1999.*
4. Alessandri Ferrero and Vincenzo Piuri, A simulation Tool for Virtual Laboratory Experiments in WWW environment, IEEE Transactions on IM, Vol. 48, 1999.
5. Kang B. Lee and Richard D. Schneeman, Internet-based Distributed Measurement and Control Application, IEEE magazine IM, June 1999.

CL 666 LOGIC AND DISTRIBUTED CONTROL SYSTEMS

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 intermediate functions: Arithmetic functions, number comparison functions, Skip and MCR functions, data move systems. PLC Advanced intermediate functions: Utilizing digital bits, sequencer functions, matrix functions. PLC Advanced functions: Alternate programming languages, analog PLC operation, networking of PLC, PLC-PID functions, PLC installation, troubleshooting and maintenance, design of interlocks and alarms using PLC. Creating ladder diagrams from process control descriptions.

Interface and backplane bus standards for instrumentation systems. Field bus: Introduction, concept. HART protocol: Method of operation, structure, operating conditions and applications. Smart transmitters, examples, smart valves and smart actuators.

Distributed control systems (DCS): Definition, Local Control (LCU) architecture, LCU languages, LCU - Process interfacing issues, communication facilities, configuration of DCS, displays, redundancy concept - case studies in DCS.

TEXT BOOKS

1. *John. W.Webb Ronald A Reis , Programmable Logic Controllers - Principles and Applications, Third edition, Prentice Hall Inc., New Jersey, 1995.*
2. *Lukcas M.P Distributed Control Systems, Van Nostrand Reinhold Co., New York, 1986.*

REFERENCES

1. *Deshpande P.B and Ash R.H, Elements of Process Control Applications, ISA Press, New York, 1995.*
2. *Curtis D. Johnson, Process Control Instrumentation Technology, Fourth edition, Prentice Hall of India, New Delhi, 1999.*

CL 667 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 668 MULTISENSOR 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 669 OPTIMAL CONTROL THEORY

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 670 STOCASTIC PROCESSES AND ESTIMATION THEORY

Introduction to Probability, Random variables. Discrete probability distribution functions. Cumulative, Joint and conditional probability density and distribution functions. Statistical Independence, Vector random variables. Expectation of a random variable, characteristic function, Central limit theorem.

Random Processes: Ensemble, examples of random processes, Markov chains, random walk and difference equations, Hidden Markov processes. Correlation. Stationary random processes. Properties of autocorrelation function. Random sequences. Cross correlation functions by ensemble averaging properties. Power spectral density function. Cross spectral density functions. Ergodic random processes.

Estimation: Introduction, development of parameter estimators, estimation of stochastic processes, applications. Least – square estimation. Linear least squares problem, generalized least square problem. Sequential least squares, non-linear least squares theory.

Characteristics of estimators: Sufficient statistics, Good estimators. Analysis of estimation errors. Mean square and minimum variance estimators.

Maximum a posteriori and maximum likelihood estimators. Numerical solution of least – squares and maximum likelihood estimation problems. Sequential estimators and some asymptotic properties.

TEXT BOOKS

1. *Childers, Probability and random processes, The McGraw-Hill companies Inc., 1997.*
2. *Harold W. Sorenson, Parameter Estimation, Principles and Problems, Marcel Dekker Inc., 1980.*

CL 671 BIOPROCESS ENGINEERING

General requirements of fermentation processes- An overview of aerobic and anaerobic fermentation processes and their application in industry - Medium requirements for fermentation processes - examples of simple and complex media - Design and usage of commercial media for industrial fermentation. Sterilization: Thermal death kinetics of micro-organisms - Batch and Continuous Heat-Sterilization of liquid Media- Filter Sterilization of Liquid Media and Air.

Enzymes: Classification and properties-Applied enzyme catalysis - Kinetics of enzyme catalytic reactions-Metabolic pathways - Protein synthesis in cells.

Stoichiometry of microbial growth, Substrate utilization and product formation-Batch and Continuous culture, Fed batch culture

Operating considerations for bioreactors for suspension and immobilized cultures, Selection, scale-up, operation of bioreactors-Mass Transfer in heterogeneous biochemical reaction systems; Oxygen transfer in submerged fermentation processes; oxygen uptake rates and determination of oxygen transfer rates and coefficients; role of aeration and agitation in oxygen transfer. Heat transfer processes in Biological systems. Recovery and purification of products.

Measurement of physical and chemical parameters in bioreactors- Monitoring and control of dissolved oxygen, pH, impeller speed and temperature in a stirred tank fermenter.

TEXT BOOKS

1. *M.L. Shuler and F. Kargi, "Bio-process Engineering", 2 Ed., Prentice Hall of India., New Delhi. 2002.*
2. *J.E. Bailey and D.F. Ollis," Biochemical Engineering Fundamentals", 2nd Edn., McGraw Hill Publishing Co. New York, 1985.*

REFERENCES

1. *P.Stanbury , A. Whitakar and S.J.Hall, " Principles of Fermentation Technology" 2nd Edn., Elsevier-Pergamon Press, 1995.*

CL 672 DIGITAL CONTROL SYSTEM DESIGN

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 673 DISCRETE OUTPUT FEEDBACK CONTROL

Lifting discrete-Time signals, Lifting Discrete time systems, fast discretization of SD systems, Design Examples, Simulation of SD systems.

Lifting continuous time signals, lifting open loop systems, lifting SD feedback systems.

Periodic output feedback control law, controller design and applications, Fast output feedback control law, controller design and applications, Simultaneous control using periodic and fast output control.

Sliding motion, Properties in the sliding mode.

Methods of hyper plane design, VSC design based on state and output feedback. Applications: Manipulator control, Flexible structure control.

REFERENCES:

1. *Tongwen Chen and Bruce Francis, "Optimal Sampled – Data Control Systems", Springer-verlag London Limited, 1995.*
2. *Gene H. Hostetter, "Digital control system design", Second Edition Holt,Rinehart and Winston, Inc.U.S, 1997.*
3. *Vadim I. Utkin, "Sliding modes in control and optimization", Springer-verlag, US 1992.*
4. *A.S.I. Zinober," Deterministic control of uncertain systems", Peter Peregrinus Ltd. London, 1990.*

CL 674 SYSTEM IDENTIFICATION

Nonparametric methods - A parametric method- Bias, consistency and model approximation- A degenerate experimental condition- the influence of feedback

Transient analysis-frequency analysis-Correlation analysis-spectral analysis.

The least Square estimate- determining the model dimension- Best linear unbiased estimation under linear constraints-updating the parameter estimates for linear regression models- Best linear unbiased estimates for linear regression models with possibly singular residual covariance matrix. Input Signals and Model parameterizations

The least squares method revisited-description of prediction error methods-optimal prediction-relationships between prediction error methods and other identification methods-theoretical analysis.

Description of instrumental variable methods- theoretical analysis-covariance matrix of VI estimates-comparison of optimal IV and prediction error estimates.

The recursive least squares method-real time identification-the recursive instrumental variable method-the recursive prediction error method.

Identifiability considerations-direct identification-indirect identification-joint input-output identification.

The parsimony principle-comparison of model structures-analysis of tests on covariance functions-asymptotic distribution of the relative decrease in the criterion function compliment. Some practical aspects

TEXT BOOKS

1. *Ljung .L, System Identification: Theory for the user, Prentice Hall, Englewood Cliffs, 1987Lennart Ljung, System Identification*
2. *Ljung, L. and Soderstorm, T., Theory and Practice of Recursive Identification, MIT Press, Cambridge, 1987.*

CL 675 REAL TIME AND EMBEDDED SYSTEM

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 VIRTUAL INSTRUMENTATION

Virtual Instrumentation: Historical perspective, advantages, block diagram and architecture of a virtual instrument, data-flow techniques, graphical programming in data flow, comparison with conventional programming. Development of Virtual Instrument using GUI, Real-time systems, Embedded Controller, OPC, HMI / SCADA software, Active X programming.

VI programming techniques: VIS and sub-VIS, loops and charts, arrays, clusters and graphs, case and sequence structures, formula nodes, local and global variables, string and file I/O, Instrument Drivers, Publishing measurement data in the web.

Data acquisition basics: 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.

VI Chassis requirements. Common Instrument Interfaces: Current loop, RS 232C/ RS485, GPIB. Bus Interfaces: USB, PCMCIA, VXI, SCSI, PCI, PXI, Firewire. PXI system controllers, Ethernet control of PXI. Networking basics for office & Industrial applications, VISA and IVI.

VI toolsets, Distributed I/O modules. Application of Virtual Instrumentation: Instrument Control, Development of process database management system, Simulation of systems using VI, Development of Control system, Industrial Communication, Image acquisition and processing, Motion control.

TEXTBOOKS

1. *Gary Johnson, LabVIEW Graphical Programming, Second edition, McGraw Hill, Newyork, 1997.*
2. *Lisa K. wells & Jeffrey Travis, LabVIEW for everyone, Prentice Hall, New Jersey, 1997.*

REFERENCES

1. *Kevin James, PC Interfacing and Data Acquisition: Techniques for Measurement, Instrumentation and Control, Newnes, 2000.*

WEB RESOURCES

www.ni.com
www.ltrpub.com

CL 677 ADAPTIVE 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 678 MICROELECTRO-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 679 ADVANCED APPLIED PROCESS 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*

CL680 PIPING AND INSTRUMENTATION

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