M.E. (CONTROL SYSTEMS ENGINEERING)

SCHEME OF INSTRUCTION AND EXAMINATION (2013 Admitted batch onwards)

Semester – I:

Subject Code	*Subject Title*	*Credits*	*Periods/week*		*Sessionals*	*Univ.exam marks*	*Total*
			Theory	*Lab*			
ECS 1.1	Advanced Control Systems	4	4	-	30	70	100
EPC 1.2	**Optimization Techniques	4	4	-	30	70	100
EPC 1.3	**Advanced Drives and Control	4	4	-	30	70	100
EPC 1.4	**Advanced Control System Design	4	4	-	30	70	100
ECS 1.5	Elective-I	4	4	-	30	70	100
ECS 1.6	Control System Simulation Lab-I	3	-	3	100	-	100
	Total	**23**	**20**	**3**			

**** Common for both ME (PSA) & ME (CSE)**

ECS 1.5 ELECTIVE -I:

(a) Large Scale Systems
(b) Digital Control Systems,
(c) Robust and Adaptive Control.

Semester – II:

Subject Code	**Subject Title**	**Credits**	**Periods/week**		**Sessionals**	**Univ.exam marks**	**Total**
			Theory	**Lab**			
ECS 2.1	Nonlinear Control Systems	4	4	-	30	70	100
ECS 2.2	Control Systems Components	4	4	-	30	70	100
EPC 2.3	**Intelligent Systems and Control	4	4	-	30	70	100
EPC 2.4	**Optimal Control Theory	4	4	-	30	70	100
ECS 2.5	Elective-II	4	4	-	30	70	100
ECS 2.6	Control System Simulation Lab-II	3	-	3	100	-	100
	Total	**23**	**20**	**3**			

**** Common for both ME (PSA) & ME (CSE)**

ECS 2.5 ELECTIVE -II:

(a) Sliding Mode Control
(b) Control of Large Scale Systems
(c) Robotics

SEMESTER III and IV : THESIS WORK

Work load : **6** Periods/Week/Student

Credits per Semester : **15**

Total Credits : **30**

The valuation of the thesis credits should be allotted but for the calculation of CGPA these credits will not be taken into consideration.

Candidates can do their work in the department or in any industry/research organization for two semesters (ie 3rd and 4th semesters). In case of thesis to be done in an industry/research organization, the advisor/advisors should be from the industry/research organization.

It is mandatory that two seminars at least one per semester related to thesis work/ general topic in III and IV semesters and publication of a paper in conference proceeding/communicated to Journal for the submission of the Thesis at the end of 4th Semester.

At the end of 4th semester, four spiral bound copies of the thesis are to be submitted to the department, out of which 2 to be retained by the department for evaluation purpose. The thesis is to be evaluated by an examiner external to the University with minimum M.E./M.Tech qualification with relevant specialization and must have minimum 5 years of experience in service.

A Viva-voce examination is to be conducted by a Committee consisting of Head of the department of respective college, Chairman, Board of Studies, the External Examiner who evaluates the thesis and the Advisor of the thesis, after receiving the evaluation report from the External Examiner.

In case the advisor happens to be HOD or Chairman, Board of Studies or from industry/research organization one more member from the department with relevant specialization is to be recommended as examiner by Chairman, Board of Studies for Viva-voce examination.

The Board will submit a report stating whether the thesis **is approved with grade** (**A - Excellent, B - Good, C – Fair, D-reappear for viva-voce)/ not approved.**

EPC 1.2: OPTIMIZATION TECHNIQUES

(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Introduction to Optimization: Introduction, Historical Development, Engineering Applications of Optimization, Statement of Optimization Problem.

Classical Optimization Techniques: Introduction, Single variable optimization, Multivariable optimization with no constraints; Multivariable optimization with Equality constraints – Solution by Direct Substitution method, Method of constrained variation, Method of Lagrangian multipliers; Multivariable optimization with inequality constraints: Kuhn-Tucker conditions.

Linear Programming: Introduction, Applications of Linear Programming, Standard Form of a Linear Programming, Basic Terminology and Definitions, Exceptional cases, Simplex method, Big-M method, Two-phase method, Revised Simplex method, Duality, Decomposition Principle.

Non-Linear Programming-I: Unconstrained optimization-Univariate method, Pattern Directions, Hook and Jeeves Method, Powell's method, Gradient of a function, Steepest descent method, Conjugate Gradient Method, Newton's method, Marquardt Method, Quai-Newton Methods, Davidon-Fletcher-Powell Method, Broyden-Fletcher-Goldfarb-Shanno Method.

Non-Linear Programming-II: Constrained optimization- Characteristics of a Constrained Problem, Sequential linear programming, Basic approach in the methods of feasible directions, Zoutendijk's method of feasible directions, Sequential Quadratic Programming.

TEXT BOOK:

1. Engineering Optimization: Theory and Applications' By S.S.Rao, New Age International Publishers, Revised Third Edition,2005.

EPC 1.3 ADVANCED DRIVES & CONTROL

(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

DC drives: System model, motor rating, motor mechanism dynamics, drive transfer function, effect of armature current waveform, torque pulsations, adjustable speed drives, chopper fed and single-phase converter fed drives, effect of field weakening.

Induction Motor drives: Basic Principle of operation of 3 Phase motor, equivalent circuit, MMF space harmonics due to fundamental current, fundamental spatial MMF distributions due to time harmonics simulation, effect of time and space harmonics, speed control by varying stator frequency and voltage, impact of nonsinusoidal excitation on induction motors, variable square wave VSI drives, variable frequency CSI drives, line frequency variable voltage drives.

Induction Motor drives: Review of induction motor equivalent circuit, effect of voltage, frequency and stator current on performance of the machine, effect of harmonics, dynamic d.q model, small signal model, voltage and current fed scalar control, direct and indirect vector control, sensor less vector control, direct torque and flux control.

Synchronous motor drives: Review of synchronous motor fundamental, equivalent circuit, dynamic d-q model, synchronous reluctance, sinusoidal and trapezoidal back emf permanent magnet motors, sinusoidal SPM machine drives, trapezoidal SPM machines drives, wound field machine drives, switched reluctance motor drives.

Closed loop control: Motor transfer function-P, PI and PID controllers, current control-Design procedure, phase locked loop (PLL) control-microcomputer control.

Text Books:

1. B. K. Bose, "Modern Power Electronics and AC drives", Pearson Education, Asia, 2003.
2. M. H. Rashid, "Power Electronics", Third Edition, PHI
3. G. K. Dubey, "Fundamentals of Electrical Drives", Narosa Publishing house.

Reference Books:

1. V. Subrahmanyam, "Electric Drives-Concepts and Applications", TMH
2. G. K. Dubey, "Power Semiconductor controlled drives", PH 1989.
3. R. Krishnan, "Electric Motor Drives: Modeling, Analysis and Control", PH, 1998.
4. P. Vas, "Sensor less vector and direct torque control", Oxford Press, 1998.
5. W. Leonard, "Control of Electric Drives", Springer Verlag, 1985.

EPC 1.4: ADVANCED CONTROL SYSTEM DESIGN

(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Design of Linear Control Systems: Review of compensation techniques to obtain desired performance, Reshaping of Bode & Root locus plots to obtain desired response, Initial condition and forced response, a simple lag – lead design.

Integral-square error compensation: parameter optimization using Integral-square error criterion with and without constraints, principles of State variable Feedback compensation of continuous - time and discrete-time systems, simple problems to understand the concept.

MIMO Control design: Principles of Linear Quadratic Optimal Regulators, Discrete Time Optimal Regulators, Observer Design, Linear Optimal Filters, State Estimate Feedback, Transfer Function Interpretation, simple problems to understand the concept.

PID Controller: PID controller, Simulation of multi-loop control system using P, PI, PD, PID controller, Standard compensator structures (P, PD, PI and PID control).

Design of digital control system: Protocol of Digital controller design, Classical Compensation of Discrete-time control systems: Forward path continuous, Forward-path Digital Z-plane Synthesis approaches, Deadbeat performance.

Text Books:

1. G. C. Goodwin, S. F. Graebe, M. E. Salgado, “Control System Design”, Prentice Hall of India
2. Gupta and Hasdorf, 'Fundamentals of Automatic control Willey Eastern, 1970.
3. B.C.Kuo, Automatic control systems' (5th Edition), Prentice Hall of India, 1988.

Reference Books:

1. M. Gopal, “Digital Control and State Variable Method”, Tata McGraw Hill
2. Hadi Saadat, “Computational Aids in Control System Using MATLAB”, McGraw Hill International
3. Ogata K., “Modern Control Engineering”, 4th Edition, Prentice Hall
4. Norman S. Nise, “Control Systems Engineering”, 3rd Edition, Wiley

SYLLABUS FOR M.E.(CONTROL SYSTEMS ENGINEERING)

SEMESTER – I

ECS 1.1: ADVANCED CONTROL SYSTEMS

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

State variable representation: Introduction-Concept of State-State equation for Dynamic Systems-Time invariance and linearity, state model-State Diagrams-Physical System.

Solution of state equation: Existence and uniqueness of solutions to Continuous-time state equations-Solution of Linear Time Varying State equations- Evaluation of matrix exponential- Role of Eigenvalues and Eigenvectors.

Controllability and Observability: Controllability and Observability-Tests for Continuous time Systems- Time varying and Time invariant case-Output Controllability-observability- System Realizations.

Stability: Introduction-Equilibrium Points-Stability in the sense of Lyapunov-BIBO Stability-Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems-Krasovskii and Variable-Gradiant Method.

Modal control: Introduction-Controllable and Observable Companion Forms-SISO and MIMO Systems-The Effect of State Feedback on Controllability and Observability-Pole Placement by State Feedback for both SISO and MIMO Systems-Full Order and Reduced Order Observers.

TEXT BOOKS:

1. M. Gopal, "Modern Control System Theory", New Age International, 2005.
2. K. Ogatta, "Modern Control Engineering", PHI, 2002.

REFERENCES:

1. John S. Bay, "Fundamentals of Linear State Space Systems", McGraw-Hill, 1999.
2. John J. D'Azzo, C. H. Houpis and S. N. Sheldon, "Linear Control System Analysis and Design with MATLAB", Taylor Francis, 2003.
3. Z. Bubnicki, "Modern Control Theory", Springer, 2005.

EPC 1.2: OPTIMIZATION TECHNIQUES

(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Introduction to Optimization: Introduction, Historical Development, Engineering Applications of Optimization, Statement of Optimization Problem.

Classical Optimization Techniques: Introduction, Single variable optimization, Multivariable optimization with no constraints; Multivariable optimization with Equality constraints – Solution by Direct Substitution method, Method of constrained variation, Method of Lagrangian multipliers; Multivariable optimization with inequality constraints: Kuhn-Tucker conditions.

Linear Programming: Introduction, Applications of Linear Programming, Standard Form of a Linear Programming, Basic Terminology and Definitions, Exceptional cases, Simplex method, Big-M method, Two-phase method, Revised Simplex method, Duality, Decomposition Principle.

Non-Linear Programming-I: Unconstrained optimization-Univariate method, Pattern Directions, Hook and Jeeves Method, Powell's method, Gradient of a function, Steepest descent method, Conjugate Gradient Method, Newton's method, Marquardt Method, Quai-Newton Methods, Davidon-Fletcher-Powell Method, Broyden-Fletcher-Goldfarb-Shanno Method.

Non-Linear Programming-II: Constrained optimization- Characteristics of a Constrained Problem, Sequential linear programming, Basic approach in the methods of feasible directions, Zoutendijk's method of feasible directions, Sequential Quadratic Programming.

TEXT BOOK:

1. **Engineering Optimization: Theory and Applications' By S.S.Rao, New Age International Publishers, Revised Third Edition,2005.**

EPC 1.3 ADVANCED DRIVES & CONTROL

(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

DC drives: System model, motor rating, motor mechanism dynamics, drive transfer function, effect of armature current waveform, torque pulsations, adjustable speed drives, chopper fed and single- phase converter fed drives, effect of field weakening.

Induction Motor drives: Basic Principle of operation of 3 Phase motor, equivalent circuit, MMF space harmonics due to fundamental current, fundamental spatial MMF distributions due to time harmonics simulation, effect of time and space harmonics, speed control by varying stator frequency and voltage, impact of nonsinusoidal excitation on induction motors, variable square wave VSI drives, variable frequency CSI drives, line frequency variable voltage drives.

Induction Motor drives: Review of induction motor equivalent circuit, effect of voltage, frequency and stator current on performance of the machine, effect of harmonics, dynamic d.q model, small signal model, voltage and current fed scalar control, direct and indirect vector control, sensor less vector control, direct torque and flux control.

Synchronous motor drives: Review of synchronous motor fundamental, equivalent circuit, dynamic d-q model, synchronous reluctance, sinusoidal and trapezoidal back emf permanent magnet motors, sinusoidal SPM machine drives, trapezoidal SPM machines drives, wound field machine drives, switched reluctance motor drives.

Closed loop control: Motor transfer function-P, PI and PID controllers, current control-Design procedure, phase locked loop (PLL) control-microcomputer control.

Text Books:

1. B. K. Bose, “Modern Power Electronics and AC drives”, Pearson Education, Asia, 2003.
2. M. H. Rashid, “Power Electronics”, Third Edition, PHI
3. G. K. Dubey, “Fundamentals of Electrical Drives”, Narosa Publishing house.

Reference Books:

1. V. Subrahmanyam, “Electric Drives-Concepts and Applications”, TMH
2. G. K. Dubey, “Power Semiconductor controlled drives”, PH 1989.
3. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control”, PH, 1998.
4. P. Vas, “Sensor less vector and direct torque control”, Oxford Press, 1998.
5. W. Leonard, “Control of Electric Drives”, Springer Verlag, 1985.

EPC 1.4: ADVANCED CONTROL SYSTEM DESIGN

(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Design of Linear Control Systems: Review of compensation techniques to obtain desired performance, Reshaping of Bode & Root locus plots to obtain desired response, Initial condition and forced response, a simple lag – lead design.

Integral-square error compensation: parameter optimization using Integral-square error criterion with and without constraints, principles of State variable Feedback compensation of continuous - time and discrete-time systems, simple problems to understand the concept.

MIMO Control design: Principles of Linear Quadratic Optimal Regulators, Discrete Time Optimal Regulators, Observer Design, Linear Optimal Filters, State Estimate Feedback, Transfer Function Interpretation, simple problems to understand the concept.

PID Controller: PID controller, Simulation of multi-loop control system using P, PI, PD, PID controller, Standard compensator structures (P, PD, PI and PID control).

Design of digital control system: Protocol of Digital controller design, Classical Compensation of Discrete-time control systems: Forward path continuous, Forward-path Digital Z-plane Synthesis approaches, Deadbeat performance.

Text Books:

1. G. C. Goodwin, S. F. Graebe, M. E. Salgado, "Control System Design", Prentice Hall of India
2. Gupta and Hasdorf, 'Fundamentals of Automatic control Willey Eastern, 1970.
3. B.C.Kuo, Automatic control systems' (5th Edition), Prentice Hall of India, 1988.

Reference Books:

1. M. Gopal, "Digital Control and State Variable Method", Tata McGraw Hill
2. Hadi Saadat, "Computational Aids in Control System Using MATLAB", McGraw Hill International
3. Ogata K., "Modern Control Engineering", 4th Edition, Prentice Hall
4. Norman S. Nise, "Control Systems Engineering", 3rd Edition, Wiley

ECS 1.5 (a): LARGE SCALE SYSTEMS
(ELECTIVE-I)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

L.S.S. Modelling : Time Domain: Introduction, Aggregation methods, exact and model aggregation by continued fraction, chained aggregation descriptive variables approach, descriptive variable systems, solvability and conditionality, time invariance, shuffle algorithm.

L.S.S. Modelling - Frequency Domain : Introduction, Moment matching, Pade approximation, Routh approximation, continued fraction method, error minimization methods, mixed methods and unstable systems, Pade model method, Pade-Routh method, multi input and multi output systems, reduction, matrix continued fraction method, Model continued fraction method, Pade model method, frequency comparison method.

Time Scales and Singular Perturbations: Introduction, problem statement and preliminaries, numerical algorithm, basic properties, relation to model aggregation, feedback control design, singularly perturbed linear systems, fast and slow sub systems, eigenvalue distribution, approximation to time scale approach, system properties, design of optimal controllers, fast and slow controllers, lower order controls.

TEXT BOOKS :

1. 'Large Scale Systems Modeling and Control', Mohammad Jamshidi,1989, North Hollard (Series in systems science and engineering, vol.9).
2. 'Large Scale Systems Modeling', Magdi S. Mohamoud and Madan G. Singh, Pergamon Press (International series on Systems and Control), 1981.

ECS 1.5 (b): DIGITAL CONTROL SYSTEMS
(ELECTIVE- I)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Discrete –Time Systems: The Structure of a Digital Control System ,Analog Systems with Piecewise Constant Inputs, Difference Equations, The Z-Transform, Z-Transform Solution of Difference Equation, The Time Response of a Discrete-Time System, Frequency Response of Discrete-Time Systems.

Modeling of Digital Control Systems: ADC Model, DAC Model, Transfer Function of the ZOH, Effect of Sampler on Transfer Function of a Cascade, Transfer Function for the DAC, Analog Subsystem, ADC Combination, Closed-Loop Transfer Function, Analog Disturbances in a Digital System, Steady-State Error and Error Constants.

Stability of Digital Control Systems: Definitions of Stability, Stable Z-Domain Pole Locations, Stability Conditions, Stability Determination, Jury Test.

State Space Representation: Discrete-Time State Space Equations, Solution of Discrete-Time State Space Equations, Z-Transfer from State Space Equations, Similarity Transformation, Stability of State Space Realizations, Controllability and Stabilizability, Observability and Detectability.

State Feedback Control: On State and Output Feedback, Pole Placement, Servo Problem, Principles of Observer, State Feedback and Pole Assignment Using Transfer Functions.

Text Books:

1. Digital control systems by B.C.Kuo, Oxford University Press

References:

1. Digital Control Engineering: Analysis and Design**,** By M. Sami Fadali, Antonio Visioli, Academic Press; 1 edition (February 16, 2009)
2. Digital control systems by K.Ogata

ECS 1.5 (c): ROBUST AND ADAPTIVE CONTROL
(ELECTIVE- I)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Part I Robust Control

Introduction: Why Robust and Adaptive Control? Control-Oriented Models for Linear-Time-Invariant Systems, Norms of Vectors and Matrices in Euclidean Spaces.

State Feedback H_∞ Optimal Control: Introduction, Norms for Signals and Systems, Power signals, Norms for Systems, Computing Norms for Systems, Well-Posedness and Stability, Stability and Performance Specifications in the Frequency Domain, Loop Shaping Using Frequency –Dependent Weights, State Feedback H_∞ Optimal Control.

Output Feedback Control: Output Feedback Using Projective Controls, Linear Quadratic Gaussian with Loop Transfer Recovery, Summary, Loop Transfer Recovery Using the Lavretsky Method.

Part II Robust Adaptive Control

Model Reference Adaptive Control: Motivational Example, Introduction to Direct Model Reference Adaptive Control, Direct Model Reference Adaptive Control of Scalar Linear Systems with Parametric Uncertainties, Historical Roots and Foundations of Model Reference Adaptive Control.

State Feedback Direct Model Reference Adaptive Control: Introduction, Command Tracking, Direct MRAC Design for Scalar Systems, Dynamic Inversion MRAC Design for Scalar Systems, MRAC Design for Multi-Input Multi-Output Systems.

Model Reference Adaptive Control with Integral Feedback Connections: Introduction, Control Design, MRAC Augmentation of an Optimal Baseline Controller.

Robust Adaptive Control: MRAC Design in the Presence of Bounded Disturbances, MRAC Design Modifications for Robustness.

Text Books:

1. Robust and Adaptive Control: With Aerospace Applications, Advanced textbooks in control and signal processing, by Eugene Lavretsky, Kevin A. Wise, publisher Springer 2012

EPC 2.3: INTELLIGENT SYSTEMS AND CONTROL
(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Neural Networks: Artificial Neural Networks: Basic properties of Neurons, Neuron Models, Feedforward networks – Perceptrons, Multilayer networks – Exact and approximate representation, Back propagation algorithm, variants of Back propagation, Unsupervised and Reinforcement learning; Competitive learning and self organizing networks, Hybrid Learning.

ANN based control: Introduction: Representation and identification, modeling the plant, control structures – supervised control, Model reference control, Internal model control, Predictive control, Case study-application to electrical engineering.

Fuzzy Logic: Overview of classical logic, Fuzzy sets vs Crisp set, Membership function, Methods of Membership function, Value Assignment, Defuzzification – Methods of defuzzification, fuzzy rule based and Approximation, Aggrigation of Fuzzy rules, Fuzzy inference system –Mamadani and Sugeno methods.

Fuzzy Controllers: Preliminaries – Basic architecture and operation of Fuzzy controller – Analysis of static properties of fuzzy controller – Analysis of dynamic properties of fuzzy controller – simulation studies – case studies –application to electrical engineering.

Neuro – Fuzzy 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, case studies –application to electrical engineering

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, PHI, New Delhi 1994.
2. Simon Haykin, Neural Networks, ISA, Research Triangle Park, 1995.
3. Bose, Nirmal K.; Bose, N. K.; Liang, Ping, Neural Network Fundamentals with Graphs, Algorithms, and Applications (McGraw-Hill Series in Electrical & Computer Engineering)
4. Robert Fuller , Introduction to Neuro-Fuzzy Systems, Springer, 2000
5. J.-S. R. Jang, C.-T. Sun, and E. Mizutani , Neuro-Fuzzy and Soft Computing
6. Berenji, Hamid R , Fuzzy and neural control (May 1, 1992)
7. Fuzzy logic with Fuzzy Applications – T.J.Ross – Mc Graw Hill Inc, 1997.
8. Fuzzy sets, Fuzzy logic, fuzzy systems by – loft Asker Zadeh
9. Timothy J Ross – Fuzzy Logic with Emergency Applications
10. Hans Jurgen Zimmerman – Fuzzy Theory and its Applications

EPC 2.4: OPTIMAL CONTROL THEORY
(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Introduction: Problem formulation- State variable representation of systems – Performance measures for optimal control problems – selecting a performance measure.

Dynamic programming: The optimal control law - principle of optimality and its application - optimal control system - interpolation - recurrence relation of dynamic programming-computational procedure for solving optimal control problems –characteristics of dynamic programming solution-analytical results-discrete linear regulator problems- Hamilton- Jacobi-Bellman equation-continuous linear regulator problems.

The Calculus of variations: Fundamental concepts- linearity of functional-closeness of functions-the increment of a functional-The variation of a functional- maxima and minima of functional- the fundamental theorem of the calculus of variations - Functional of a single function- the simplest variational problem

The variational approach to optimal control problems: Necessary conditions for optimal control - Linear regulator problem-Pontryagin's minimum principle and state inequality constraints.

Iterative numerical techniques for finding optimal controls: Two-point boundary-value problems-The method of steepest descent-Features of the steepest descent algorithm.

TEXT BOOK:

1. Optimal control theory-An Introduction by Donald E.Kirk - Prentice Hall Networks series.

<u>SYLLABUS FOR M.E.</u>(CONTROL SYSTEMS ENGINEERING)

<u>SEMESTER – II</u>

ECS 2.1 : NON-LINEAR CONTROL SYSTEMS

Credits **: 4**
Lectures per week : **4**
Theory, Univ. Exam. Marks : **70**
Sessional Marks : **30**
Total Marks : **100**

Introduction to Non-Linear System: Classification of non-linearity, types of non-linearity in physical system, jump phenomena and critical jump resonance curve, methods of analysis of non-linear systems and comparison, isoclines, singular point, limit cycle.

Phase Plane Analysis: Concept of phase plane, phase trajectory, phase portraits, methods of plotting phase plane trajectories Vander Pol's equation, stability from phase portrait, time response from trajectories, isoclines method, Pell's method of phase trajectory, and Delta method of phase trajectory construction.

Frequency Domain Analysis: Absolute stability, Describing function, DF of typical nonlinearities stability analysis using DF method, stability studies using DF method.

Liapunov Stability: Autonomous Systems: Stability of equilibrium point. Concepts of positive definite/semi definite, negative definite/ semi definite, indefinite functions, Lyapunov function, Liapunov Stability: asymptotic stability, global asymptotic stability, instability.

Linearization: Linear systems, linearization of nonlinear systems about equilibrium point, **f**eedback linearization and input/output linearization.

TEXT BOOK:

1. M.Vidyasagar, 'Nonlinear systems Analysis', 2nd Edition, 1991, prentice-Hall Inc.

REFERENCE BOOK:

1. Control Systems Theory and Application: Samarjit Ghosh, Pearson Education
2. Control System Engineering: Nagrath and Gopal, Wiley Eastern
3. Automatic Control System: George J. Thaler Brown, Jaico Publications
4. Nonlinear Systems: Hasan A. Khalil, Printece Hall of India

ECS 2.2: CONTROL SYSTEM COMPONENTS:

Credits : **4**
Lectures per week : **4**
Theory, Univ. Exam. Marks : **70**
Sessional Marks : **30**
Total Marks : **100**

Gyroscopes and Potentiometers: Working of gyroscopes, types of gyroscopes and their generalized mathematical model, applications of horizontal and vertical gyroscopes. Types of potentiometers, applications of potentiometers and selection of potentiometers.

Tachometers and Synchros: Construction details, e.m.f equation of tachometers, types of tachometers, characteristics of tachometers, tachometer applications. Constructional details and working of Synchros, Principles of Resolvers and Decoders,

Stepper Motors and Servomotors: Working principle of Stepper motor, types – permanent magnet stepper motor, reluctance type stepper motor, hybrid stepper motor, Applications of stepper motor. Servomotors types, DC servomotors, AC servomotors – transfer functions, speed control methods (armature controlled & field controlled).

Magnetic Amplifiers and Servo Amplifiers: construction, types of magnetic amplifiers – series, parallel and self saturated magnetic amplifiers, Characteristics of magnetic amplifiers, features of servo amplifiers, DC and AC servo amplifiers.

MEMS and Accelerometers: Introduction to MEMS, definitions, classification and applications. Introduction to the Accelerometer and types of accelerometers.

TEXT BOOK:

1. Gibson T.E. and Tetuer F.B, "Control System Components", McGraw Hill, New York 1993.

REFERENCE BOOKS:

1. Greenwood, "Mechanical details of product design", McGraw Hill, New York, 1990.
2. Nadim Maluf and Kirt Williams "An Introduction to Microelectromechanical Systems Engineering"Second edition

EPC 2.3: INTELLIGENT SYSTEMS AND CONTROL
(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Neural Networks: Artificial Neural Networks: Basic properties of Neurons, Neuron Models, Feedforward networks – Perceptrons, Multilayer networks – Exact and approximate representation, Back propagation algorithm, variants of Back propagation, Unsupervised and Reinforcement learning; Competitive learning and self organizing networks, Hybrid Learning.

ANN based control: Introduction: Representation and identification, modeling the plant, control structures – supervised control, Model reference control, Internal model control, Predictive control, Case study-application to electrical engineering.

Fuzzy Logic: Overview of classical logic, Fuzzy sets vs Crisp set, Membership function, Methods of Membership function, Value Assignment, Defuzzification – Methods of defuzzification, fuzzy rule based and Approximation, Aggrigation of Fuzzy rules, Fuzzy inference system –Mamadani and Sugeno methods.

Fuzzy Controllers: Preliminaries – Basic architecture and operation of Fuzzy controller – Analysis of static properties of fuzzy controller – Analysis of dynamic properties of fuzzy controller – simulation studies – case studies –application to electrical engineering.

Neuro – Fuzzy 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, case studies –application to electrical engineering

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, PHI, New Delhi 1994.
2. Simon Haykin, Neural Networks, ISA, Research Triangle Park, 1995.
3. Bose, Nirmal K.; Bose, N. K.; Liang, Ping, Neural Network Fundamentals with Graphs, Algorithms, and Applications (McGraw-Hill Series in Electrical & Computer Engineering)
4. Robert Fuller , Introduction to Neuro-Fuzzy Systems, Springer, 2000
5. J.-S. R. Jang, C.-T. Sun, and E. Mizutani , Neuro-Fuzzy and Soft Computing
6. Berenji, Hamid R , Fuzzy and neural control (May 1, 1992)
7. Fuzzy logic with Fuzzy Applications – T.J.Ross – Mc Graw Hill Inc, 1997.
8. Fuzzy sets, Fuzzy logic, fuzzy systems by – loft Asker Zadeh
9. Timothy J Ross – Fuzzy Logic with Emergency Applications
10. Hans Jurgen Zimmerman – Fuzzy Theory and its Applications

EPC 2.4 : OPTIMAL CONTROL THEORY
(COMMON FOR POWER SYSTEMS AND AUTOMATION & CONTROL SYSTEM ENGINEERING)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Introduction: Problem formulation- State variable representation of systems – Performance measures for optimal control problems – selecting a performance measure.

Dynamic programming: The optimal control law - principle of optimality and its application - optimal control system - interpolation - recurrence relation of dynamic programming-computational procedure for solving optimal control problems –characteristics of dynamic programming solution-analytical results-discrete linear regulator problems- Hamilton- Jacobi-Bellman equation-continuous linear regulator problems.

The Calculus of variations: Fundamental concepts- linearity of functional-closeness of functions-the increment of a functional-The variation of a functional- maxima and minima of functional- the fundamental theorem of the calculus of variations - Functional of a single function- the simplest variational problem

The variational approach to optimal control problems: Necessary conditions for optimal control - Linear regulator problem-Pontryagin's minimum principle and state inequality constraints.

Iterative numerical techniques for finding optimal controls: Two-point boundary-value problems- The method of steepest descent-Features of the steepest descent algorithm.

TEXT BOOK:

1. Optimal control theory-An Introduction by Donald E.Kirk - Prentice Hall Networks series.

ECS 2.5 (a): SLIDING MODE CONTROL
(ELECTIVE - II)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

An Introduction to Sliding Mode Control: Introduction, properties of sliding motion, typical controller design, pseudo-sliding with a smooth control action, a state-space approach

Sliding mode control: Introduction, problem statement, existence of solution and equivalent control properties of the sliding motion, The reachability problem, the unit vector approach, continuous approximations.

Sliding mode Design approaches: Introduction, A regulator form based approach, a direct eigenstructure assignment approach, Incorporation of a tracking requirement, Design study of Pitch-pointing flight controller.

Sliding mode controllers using output information: Introduction, problem formulation, a special case of square plants, a general frame work, dynamic compensation, observer based dynamic compensation, a model reference system using only outputs.

Sliding mode observers: Introduction, sliding mode observers, synthesis of a discontinuous observer, the Walcott-Zak observer revisited, sliding mode observers for fault detection

TEXT BOOK:

1. Sliding Mode Control: Theory And Applications (Series in Systems and Control) by ,C Edwards and S Spurgeon, Published by Taylor & Francis,

REFERENCE:

2. Sliding Mode Control In Engineering (Automation and Control Engineering) by Wilfrid Perruquetti , Jean-Pierre Barbot published by Marcel Dekker, Inc, New York

ECS 2.5 (b): CONTROL OF LARGE SCALE SYSTEMS
(ELECTIVE- II)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Hierarchical Control of Large Scale Systems: Introduction- Coordination of Hierarchical Structures - open Loop and closed loop Hierarchical control of control of continuous - time systems-Hierarchical control of Discrete time approach - Costal prediction approach.

Decentralized control of Large Scale Systems: Introduction - problem formulation of decentralized stabilization - fixed polynomials and fixed modes - stabilization via dynamic compensation -stabilization Via local state feedback - stabilization Via Multilevel control.

Near -optimum control Design of large systems: Near optimum control of LTI systems - Aggregation methods perturbation methods - Multi time - scale approach - Hierarchical and decentralized methods - Bounds on Near - optimal cost functional - Near optimality due to aggregation - Near optimality due to perturbation Near optimality in Hierarchical control with structural perturbation.

TEXT BOOK:

1. Large scale systems modelling and control, Mobamma Jamshidi, 1983, North-Hochand (Chapters 4, 5 and 6).

ECS 2.5 (c): ROBOTICS
(ELECTIVE- II)

Credits	**: 4**
Lectures per week	: **4**
Theory, Univ. Exam. Marks	: **70**
Sessional Marks	: **30**
Total Marks	: **100**

Fundamentals of Robot Technology: Basic structure, links and Joints, types of Joints, types of links, types of end effectors: Grippers: Mechanical, Vacuum cups, Magnetic, adhesive and miscellaneous. Tools as end effectors. Wrist configuration: concept of: yaw, pitch and roll.

Robot classification: according to 1) Co-ordinate system: Cartesian, cylindrical, spherical, SCARA, Articulated 2) Control Method: Servo controlled and non-servo controlled, their comparative study 3) Form of motion: P-T-P (point to point), C-P (continuous path), pick and place etc. and their comparative study 4) Motion conversion: Rotary to rotary, rotary to linear and vice versa.

Robot arm dynamics: Newton Euler Equations, Kinetic and potential energy, Lagrangian analysis for a single prismatic joint working against gravity and single revolute joint. Joint vector, homogeneous co-ordinates. Matrix operators for translation and rotation

Robot Control: Open loop and closed loop control, Linear control Schemes, PD and PID control, Torque and Force control of robotic manipulators, Adaptive control, Hybrid control, Impedance control. Manipulator Jacobian, Jacobian for prismatic and revolute joint. Jacobian Inverse, Singularities, Control of Robot manipulator: joint position controls (JPC), resolved motion position controls (RMPC) and resolved motion rate control (RMRC)

Industrial Applications: Industrial Applications of Robots: Welding, Spray-painting, Grinding, Handling of rotary tools, Parts handling/transfer, Assembly operations, parts sorting, parts inspection, Potential applications in Nuclear and fossil fuel power plant etc.

TEXT BOOKS:

1. R. K. Mittal, I. J. Nagrath, "Robotics and Control", Tata McGraw Hill Publishing Company Ltd., New Delhi.

REFERENCE BOOKS:

1. Arthur J. Critchlow, "Introduction to Robotics"
2. Robert J. Schilling, "Fundamentals of Robotics: Analysis and Control", Prentice Hall of India, New Delhi
3. John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education
4. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey, "Industrial Robotics: Technology, Programming and Applications", McGraw Hill Book Company
5. Richard D. Klafter, Thomas A. Chemielewski, Michael Neign "Robotic Engineering – An Integral Approach", Prentice Hall of India Pvt. Ltd., New Delhi. Eastern Economy Edition.
6. K. S. Fu., R. C. Gonzalez, C. S. G. Lee, "Robotics: Control Sensing, Vision and Intelligence", International Edition, McGraw Hill Book Co.