KERALA TECHNOLOGICAL UNIVERSITY

Master of Technology

Curriculum, Syllabus and Course Plan

Cluster	:	*01*
Branch	:	*Electrical & Electronics Engineering*
Stream	:	*Control Systems*
Year	:	*2015*
No. of Credits	:	*67*

SEMESTER 1

Examination Slot	Course Number	Name	L-T-P	Internal Marks	End Semester Examination		Credits
					Marks	Duration (hours)	
A	01MA6021	Advanced Mathematics & Optimization Techniques	3-0-0	40	60	3	3
B	01EE6101	Dynamics of Linear Systems	3-1-0	40	60	3	4
C	01EE6103	Digital Control Systems	3-1-0	40	60	3	4
D	01EE6303	Power Electronic Circuits	3-0-0	40	60	3	3
E	01EE6203	Introduction to Flight	3-0-0	40	60	3	3
S	01EE6999	Research Methodology	0-2-0	100			2
T	01EE6191	Seminar I	0-0-2	100			2
U	01EE6193	Design & Simulation Lab	0-0-2	100			1
		TOTAL	**15-4-4**	**500**	**300**	**-**	**22**

TOTAL CONTACT HOURS : 23
TOTAL CREDITS : 22

SEMESTER 2

Examination Slot	Course Number	Name	L-T-P	Internal Marks	End Semester Examination		Credits
					Marks	Duration (hours)	
A	01EE6102	Optimal Control Theory	3-1-0	40	60	3	4
B	01EE6104	Nonlinear Control Systems	3-0-0	40	60	3	3
C		Elective-I	3-0-0	40	60	3	3
D		Elective-II	3-0-0	40	60	3	3
E		Elective-III	3-0-0	40	60	3	3
V	01EE6192	Mini Project	0-0-4	100			2
U	01EE6194	Advanced Control Lab	0-0-2	100			1
		TOTAL	**15-1-6**	**400**	**300**	**-**	**19**

TOTAL CONTACT HOURS : 22
TOTAL CREDITS : 19

Elective I

01EE6112 Process Control & Industrial Automation

01EE6114 Adaptive Control

01EE6412 New and Renewable Sources of Energy

01EE6314 PWM Converters and Applications

Elective II

01EE6116 Sliding Mode Control

01EE6118 Stochastic Control

01EE6122 Industrial Data Networks

01EE6432 Sustainable and Translational Engineering

Elective III

01EE6124 Robotics and Control

01EE6126 Soft Computing Techniques

01EE6214 Flight Dynamics and Control

01EE6426 Smart Grid Technologies and Applications

SEMESTER 3

Examination Slot	Course Number	Name	L-T-P	Internal Marks	End Semester Examination		Credits
					Marks	Duration (hours)	
A		Elective IV	3-0-0	40	60	3	3
B		Elective V	3-0-0	40	60	3	3
T	01EE7191	Seminar II	0-0-2	100			2
W	01EE7193	Project (Phase 1)	0-0-12	50			6
		TOTAL	**6-0-14**	**230**	**120**	**-**	**14**

TOTAL CONTACT HOURS : 20
TOTAL CREDITS : 14

Elective IV

01EE7111 Robust Control
01EE7113 Advanced Instrumentation
01EE7115 System Identification & Parameter Estimation
01EE7313 Dynamics of Power Converters

Elective V

01EE7117 Estimation Theory
01EE7119 Multivariable Control Theory
01EE7121 Biomedical Instrumentation
01EE7315 Hybrid Electric Vehicles

SEMESTER 4

Examination Slot	Course Number	Name	L-T-P	Internal Marks	End Semester Examination		Credit
					Marks	Duration (hours)	
W	01EE7194	Project (Phase 2)	0-0-23	70	30		12
		TOTAL	**0-0-23**	**70**	**30**	**-**	**12**

TOTAL CONTACT HOURS : 23
TOTAL CREDITS : 12

TOTAL NUMBER OF CREDITS: 67

SEMESTER – I

Syllabus and Course Plan

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01MA6021	Advanced Mathematics & Optimization Techniques	**3-0-0**	**3**	**2015**

Course Objectives

1. Develop a conceptual basis for Linear algebra.
2. Equip the Students with a thorough understanding of vector spaces and optimization techniques.

Syllabus

Vector Spaces - linear Transformations - orthogonality - least square solutions - matrix factorizations - Linear programming problems - Simplex Methods - Integer programming - Non-linear programming (Unconstrained and constrained) - quadratic programming - Convex programming - Dynamic programming

Expected Outcome

Upon successful completion of the course, students will have basic knowledge of vector spaces and optimization theory which are essential for higher studies and research in Engineering.

References

1. David C. Lay, Linear Algebra, Pearson Education, 4/e, 2012
2. Handy A. Taha, Operations Research an Introduction, PHI, 9/e, 2011
3. R. Hariprakash and B. Durga Prasad, Operations Research, Scitech. 1/e, 2010
4. B. S. Goel and S. K. Mittal, Operations Research, PragathiPrakashan, 25/e, 2009
5. Seymour Lipschulz, Linear Algebra, Tata McGraw Hill.
6. K. V. Mittal and C. Mohan, Optimization Methods in Operations Research and System Analysis, 3/e, New Age International Publishers.
7. Singiresu S Rao, Engineering Optimization Theory and Practice, 3/e, New Age International Publishers.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Vector spaces and subspaces, null space, column space of a matrix; linearly independent sets and bases; Coordinate systems; dimension of a vector space; rank; change of basis; linear transformations – properties - kernel and range - computing kernel and range of a linear transformation - matrix representation of a linear operator - Invertible linear operators	7	15

II	Inner product, length and orthogonality; orthogonal sets; orthogonal projections; Gram Schmidt process; least square solutions; Inner product spaces; QR factorization ; Singular value decomposition.	7	15
FIRST INTERNAL EXAM			
III	Linear programming problems - Simplex Methods - two phase simplex method-Dual simplex method, Integer linear programming; Graphical representation - Gomory's Cutting plane method, Zero – One Programming	7	15
IV	Unconstrained non-linear programming; Steepest descent method, Conjugate Gradient method, Powel's method, Hooke-Jeeves method.	7	15
SECOND INTERNAL EXAM			
V	Constrained non-linear programming - Complex method - Cutting plane method - method of feasible directions - Kuhn-Tucker conditions	7	20
VI	Convex programming problem - Exterior penalty method - Quadratic programming - Dynamic programming - representation of multi stage decision process – sub-optimization and principle of optimality - computational procedure in dynamic programming	7	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6101	Dynamics of Linear Systems	**3-1-0**	**4**	**2015**

Course Objectives

1. To provide a strong foundation on classical and modern control theory.
2. To provide an insight into the role of controllers in a system.
3. To design compensators using classical methods.
4. To design controllers in the state space domain.
5. To impart an in depth knowledge in observer design

Syllabus

Design of feedback control systems- Review of compensator design using Root locus and Bode plots- PID controllers , State Space Analysis and Design- Solution of Linear Time Varying Systems-Linear state variable feedback for SISO systems-formulae for feedback gain-Transfer function approach-controllable and uncontrollable modes - regulator problems,Asymptotic observers for state measurement-implementation of the observer-full order and reduced order observers-combined observer–controller-direct transfer function design procedures-MIMO systems: Introduction-controllability-observability- different companion forms for MIMO systems.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Analyze a given system and assess its performance.
2. Design a suitable compensator to meet the required specifications.
3. Design and tune PID controllers for a given system.
4. Realize a linear system in state space domain and to evaluate controllability and observability.
5. Design a controller and observer for a given system and evaluate its performance.

References

1. Thomas Kailath, Linear System, Prentice Hall Inc., Eaglewood Cliffs, NJ, 1998
2. M. Gopal, Control Systems-Principles and Design, Tata McGraw-Hill.
3. Richard C. Dorf& Robert H. Bishop, Modern Control Systems Pearson Education, Limited, 12th Ed., 2013
4. Gene K. Franklin & J. David Powell, Feedback Control of Dynamic Systems, Pearson Education, 5th Edition, 2008
5. Friedland B., Control System Design: An Introduction to State Space Methods, Courier Corporation, 2005

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Design of feedback control systems- Approaches to system design-compensators–performance measures- cascade compensation networks-phase lead and lag compensator design using both Root locus and Bode plots	7	15
II	PID controllers-effect of proportional, integral and derivative gains on system performance-PID tuning-integral windup and solutions	7	15
FIRST INTERNAL EXAM			
III	State Space Analysis and Design- Analysis of stabilization by pole cancellation- reachability and constructability - stabilizability - controllability - observability-grammians-Analysis of stabilization by output feedback-Transfer function approach - state feedback and zeros of the transfer function.Solution of Linear Time Varying Systems	10	15
IV	Linear state variable feedback for SISO systems, -modal controllability-formulae for feedback gain -significance of controllable Canonic form-Ackermann's formula feedback gains in terms of Eigen values - Mayne-Murdoch formula - non controllable realizations and stabilizability - controllable and uncontrollable modes - regulator problems .	12	15
SECOND INTERNAL EXAM			
V	Observers: Asymptotic observers for state measurement-open loop observer-closed loop observer-formulae for observer gain -implementation of the observer - full order and reduced order observers - separation principle - combined observer -controller – optimality criterion for choosing observer poles	10	20
VI	Direct transfer function design procedures – Design using polynomial equations - Direct analysis of the Diophantine equation. MIMO systems: Introduction, controllability, observability, different companion forms for MIMO systems	10	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6103	Digital Control Systems	3-1-0	**4**	**2015**

Course Objectives

1. Introduce the concepts of digital control of dynamic systems, design using transform techniques and state space methods
2. To design compensators using classical methods and analyse the closed-loop stability
3. To impart in-depth knowledge in state space design of digital controllers and observers
4. To analyse the system performance and stability aspects with controller and observer in closed-loop

Syllabus

Review of Z Transforms-Analysis in Z-domain-Discrete Systems- Pulse Transfer Function-Significance of Sampling- mapping between s-plane and z-plane-Stability analysis of closed-loop systems in the z-plane- Discrete equivalents-Digital Controller Design for SISO systems-design by Emulation- direct design- using root locus-frequency response methods and State-Space approach- method of Ragazzini- discretization of continuous time state-space equations-Controllability- Observability-Control Law Design- Pole Placement- State Feedback-Digital PID-design of PID controller based on frequency response method- Design of lag, lead and lag-lead compensators-Estimator/Observer Design- Full order observers- reduced order observers-Regulator Design-Separation Principle-Introduction to MIMO systems-Design Concept - Case Study

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Analyse a discrete-time system and evaluate its performance
2. Design suitable digital controller for the system to meet the performance specifications
3. Design a digital controller and observer for the system and evaluate its performance

References

1. Gene F. Franklin, J. David Powell, Michael Workman, Digital Control of Dynamic Systems, Pearson, Asia.
2. J. R. Liegh, Applied Digital Control, Rinchart& Winston Inc., New Delhi.
3. Benjamin C. Kuo, Digital Control Systems, 2/e, Saunders College Publishing, Philadelphia, 1992.
4. K. Ogata, Discrete-Time Control Systems, Pearson Education, Asia.
5. C. L. Philips, H. T. Nagle, Digital Control Systems, Prentice-Hall, Englewood Cliffs, New Jersey, 1995.
6. R. G. Jacquot, Modern Digital Control Systems, Marcel Decker, New York, 1995.
7. M. Gopal, Digital Control and State Variable Methods, Tata McGraw-Hill, 1997.
8. Frank L. Lewis,Applied Optimal Control& Estimation, Prentice-Hall, Englewood Cliffs NJ, 1992.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**% of Marks in End-Semester Examination**
I	Review of Z Transforms, Analysis in Z-domain, Discrete Systems, Sampling Theorem, Sample and Hold, Sampling Rate Selection, Pulse Transfer Function, Mapping between the s-plane and the z-plane	7	15
II	Stability analysis of closed-loop system in the z-plane, Jury's test, Schur-Cohn test, Bilinear Transformation, Routh-Hurwitz method in w-plane. Discrete equivalents; via numerical integration, pole-zero matching, hold equivalents	7	15
FIRST INTERNAL EXAM			
III	Digital Controller Design for SISO systems: design by Emulation, direct design based on root locus in the z-plane, direct design based on frequency response methods, direct design-method of Ragazzini - Case Study	10	15
IV	Design using State-Space approach, discretization of continuous time state-space equations, Controllability, Observability, Control Law Design; Pole Placement, State Feedback - Case Study.	12	15
SECOND INTERNAL EXAM			
V	Digital PID; design of PID controller based on frequency response method, Design of lag, lead and lag-lead compensators - Case Study	10	20
VI	Estimator/Observer Design: Full order observers - reduced order observers, Regulator Design, Separation Principle - case with reference input, MIMO systems; Introduction to MIMO systems, Design Concept - Case Study	10	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6303	Power Electronic Circuits	3-0-0	3	2015

Course Objectives:

1. To develop a deep knowledge of Power Semiconductor Devices, Power Electronic Circuits and their applications.
2. To analyse AC/DC and DC/AC converters.
3. To analyse DC/DC converters.
4. To develop skills to use Power Electronic Circuits in energy conversion systems.

Syllabus

Power Electronic Elements – Switches, switching constraints, characteristics, losses, switch models. AC voltage controller –performance, sequential controller. DC/DC converter – Buck converter, boost converter, buck- boost converter, cuk converter, Volt-sec balance, ripples, discontinuous conduction mode. Isolated DC/DC converters- flyback, forward, push pull and bridge topology. Switched mode inverters – Topologies. Voltage source inverter- PWM operation, dwell time, current controlled voltage source inverter, current source inverter and analysis.

Expected Outcome:

Upon successful completion of this course, students will be able to analyse and design various types of Power Electronics Circuits. They will acquire skills to apply Power Electronic Circuits in Power Converters to improve the performance and efficiency.

REFERENCES

1. Ned Mohan, et al., Power Electronics: Converters, Design and Applications, Wiley
2. Joseph Vithayathil, "Power Electronics: Principles and Applications", Tata McGraw Hill.
3 V. Ramanarayanan, "Course Notes on Switched Mode Power Converters", Department of Electrical Engineering, Indian Institute of Science, Bangalore.
4 G. K. Dubey, et.al., "Thyristorised Power Controllers", New Age International
5 Bin Wu, High Power Converters and AC Drives, IEEE Press, Wiley Interscience, 2006.

COURSE PLAN

Module	Contents	Hours	End semester exam % marks
1	Power Electronic Elements: The ideal switch, Characteristics of ideal switches, two-quadrant and four-quadrant switches- Switching constraints in power electronic circuits-Practical switches: Static and dynamic characteristics of Power Diodes, MOSFETs, IGBTs and GTOs-implementations of different configurations of switches using semiconductor devices.	7	15

2	Losses in practical switches: Models of diode, MOSFET and IGBTs for evaluating conduction and switching losses. AC voltage controllers: Analysis of single-phase ac voltage controller with R and RL load, Performance parameters, Sequential control of single-phase ac voltage controllers.	8	15
	First Internal Exam		
3	DC-DC converters: Buck, boost, buck-boost and Ćuk Topologies- Steady state analysis in continuous conduction mode using inductor volt-sec balance - current and voltage ripples. Design relations for inductor and capacitors. Discontinuous Conduction Mode operation of basic buck and boost converter.	8	15
4	Isolated DC-DC converters: Steady-state analysis of flyback, forward, push-pull and bridge topologies.	7	15
	Second Internal Exam		
5	Switched Mode Inverters: Topologies of single-phase half-bridge, full-bridge and three-phase bridge Voltage Source Inverters - stepped wave and PWM operation- Sine-Triangle PWM-Selective Harmonic Elimination--Space Vector PWM-Evaluation of dwell times.	6	20
6	Principles of Current-Controlled VSI- Hysteresis control and PWM current control. Current Source Inverters: Analysis of capacitor commutated single phase CSI feeding resistive and pure-inductor loads.	6	20
	End Semester Exam		

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6203	Introduction to Flight	3-0-0	**3**	**2015**

Course Objectives

To give basic concepts of aerodynamics, principles and performance of aircrafts.

Syllabus

Fundamentals of aerodynamics-standard atmosphere-aerodynamic flows-airfoils -aerodynamic forces moments and coefficients-wind tunnels- control surfaces-anatomy of aerospace vehicles.

Expected Outcome

Upon successful completion of this course, students will have an understanding of the standard atmosphere, performance of flight.

References

1. 1. John D Anderson Jr, 'Introduction to Flight' McGraw Hill International, 5/e,2005
2. John D Anderson Jr, 'Fundamentals of Aerodynamics', Me Graw Hill International, 4/e, 2007.
3. A.C.Kermode, ''Mechanics of Flight', Pearson Education, 10/e, 2005.
4. Bernard Etkin, 'Dynamics of flight Stability and Control', John Wiley and Sons Inc. 3/e, 1996.
5. E.L.Houghton and N.B.Carruthers 'Aerodynamics for Engineering Students', Arnold Publishers, 3/e, 1986.
6. Thomas R.Yechout, 'Introduction to Aircraft Flight Mechanics', A1AA Education Series, 2003
7. Richard S.Shevell, 'Fundamentals of Flight' Pearson Education Inc., 2/e , 2004.
8. Louis V. Schmidt 'Introduction to Aircraft Flight Dynamics', AIAA Education Series, 1997

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Aerodynamics-standard atmosphere-definition of altitudes- density, pressure and temperature altitudes-layers of atmosphere- isothermal and gradient layers-calculation of pressure, temperature and density in	6	15

	stratosphere and troposphere-lapse rate –stability of atmosphere.		
II	Aerodynamic flows-inviscid and viscous flows-incompressible and compressible flows-Mach number-subsonic, transonic, supersonic and hypersonic flow regimes-boundary layer-laminar and turbulent flows-Reynolds number.	6	15
FIRST INTERNAL EXAM			
III	Pressure and shear stress distribution-vorticity and circulation-downwash and induced drag- wash-in and wash-out- dimensional analysis-Buckingham Pi theorem-aerodynamic forces and moments-aerodynamic heating-dynamic pressure-pressure coefficient-compressibility-isentropic flow-speed of sound.	8	15
IV	Airfoils-airfoil nomenclature-symmetric and cambered airfoils-pressure distribution over airfoil-generation of lift-lifting surfaces-wings-wing geometry-aspect ratio-chord line –angle of attack-characteristics of ideal airfoil-stalling of airfoil-lift curve, drag curve and lift/drag ratio curve-NACA airfoils-modern low speed airfoils-super critical airfoils-swept wings.	7	15
SECOND INTERNAL EXAM			
V	Aerodynamic coefficients-lift, drag and moment coefficients-variation with angle of attack-aerodynamic centre andcentre of pressure-critical Mach number-drag divergence Mach number-Mach angle-Mach number independence-flow similarity-drag polar.	8	20
VI	Wind tunnels-open, close and variable density wind tunnels-control surfaces-elevator-aileron-rudder-canard-tail plane-loads on tail plane-dihedral angle-dihedral effect-flaps and slots-spoilers-Classification of aerospace vehicles-aircrafts helicopters-launch vehicles-missiles-unmanned aerial vehicles and spacecraft. Basic concepts of high speed aerodynamics and aero elasticity.	7	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6999	Research Methodology	0-2-0	2	2015

Course Objectives

1. To prepare the student to do the M. Tech project work with a research bias.
2. To formulate a viable research question.
3. To develop skill in the critical analysis of research articles and reports.
4. To analyze the benefits and drawbacks of different methodologies.
5. To understand how to write a technical paper based on research findings.

Syllabus

Introduction to Research Methodology-Types of research- Ethical issues- Copy right-royalty-Intellectual property rights and patent law-Copyleft- Openacess-
Analysis of sample research papers to understand various aspects of research methodology:
Defining and formulating the research problem-Literature review-Development of working hypothesis-Research design and methods- Data Collection and analysis- Technical writing- Project work on a simple research problem

Approach

Course focuses on students' application of the course content to their unique research interests. The various topics will be addressed through hands on sessions.

Expected Outcome

Upon successful completion of this course, students will be able to
1. Understand research concepts in terms of identifying the research problem
2. Propose possible solutions based on research
3. Write a technical paper based on the findings.
4. Get a good exposure to a domain of interest.
5. Get a good domain and experience to pursue future research activities.

References

1. C. R. Kothari, Research Methodology, New Age International, 2004
2. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.
3. J. W. Bames, Statistical Analysis for Engineers and Scientists, Tata McGraw-Hill, New York.
4. Donald Cooper, Business Research Methods, Tata McGraw-Hill, New Delhi.
5. Leedy P. D., Practical Research: Planning and Design, McMillan Publishing Co.
6. Day R. A., How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
7. Manna, Chakraborti, Values and Ethics in Business Profession, Prentice Hall of India, New Delhi, 2012.
8. Sople, Managing Intellectual Property: The Strategic Imperative, Prentice Hall ofIndia, New

Delhi, 2012.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Introduction to Research Methodology: Motivation towards research - Types of research: Find examples from literature. Professional ethics in research - Ethical issues-ethical committees. Copy right - royalty - Intellectual property rights and patent law - Copyleft- Openacess-Reproduction of published material - Plagiarism - Citation and acknowledgement. Impact factor. Identifying major conferences and important journals in the concerned area. Collection of at least 4 papers in the area.	5	
II	Defining and formulating the research problem -Literature Survey- Analyze the chosen papers and understand how the authors have undertaken literature review, identified the research gaps, arrived at their objectives, formulated their problem and developed a hypothesis.	4	
FIRST ASSESSMENT			
III	Research design and methods: Analyze the chosen papers to understand formulation of research methods and analytical and experimental methods used. Study of how different it is from previous works.	4	No end semester written examination
IV	Data Collection and analysis.Analyze the chosen papers and study the methods of data collection used. - Data Processing and Analysis strategies used– Study the tools used for analyzing the data.	5	
SECOND ASSESSMENT			
V	Technical writing - Structure and components, contents of a typical	5	

	technical paper, difference between abstract and conclusion,layout, illustrations and tables, bibliography, referencing and footnotes-use of tools like Latex.		
VI	Identification of a simple research problem – Literature survey- Research design- Methodology –paper writing based on a hypothetical result.	5	
END SEMESTER ASSESSMENT			

Course No.	**Course Name**	**L-T-P**	**Credits**	**Year of Introduction**
01EE6191	Seminar I	0-0-2	2	2015

Course Objectives

To make students

1. Identify the current topics in the specific stream.
2. Collect the recent publications related to the identified topics.
3. Do a detailed study of a selected topic based on current journals, published papers and books.
4. Present a seminar on the selected topic on which a detailed study has been done.
5. Improve the writing and presentation skills.

Approach

Students shall make a presentation for 20-25 minutes based on the detailed study of the topic and submit a report based on the study.

Expected Outcome

Upon successful completion of the seminar, the student should be able to

1. Get good exposure in the current topics in the specific stream.
2. Improve the writing and presentation skills.
3. Explore domains of interest so as to pursue the course project.

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6193	Design and Simulation Lab	0-0-2	**1**	**2015**

Course Objectives

1. Analyse systems using classical and modern control theory using MATLAB/SIMULINK
2. Design, simulate and evaluate control systems.
3. Design & fine tuning of PID controller and familiarize the roles of P, I and D in feedback control

Syllabus

Familiarization of Control System Toolbox of MATLAB; Analysis of systems using classical and modern control theory using MATLAB and SIMULINK; Compensator design based on time domain and frequency domain approaches for a given system, state feedback control; full order observer; reduced order observer to implement a state feedback controller, numerical methods using MATLAB

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Acquire ability to critically analyze different dynamic systems and choose a suitable controller.
2. Get exposure to aspects of control systems design.
3. Get exposure to simulation tools using MATLAB/SIMULINK

COURSE PLAN

Experiment No:	Title	Hours Allotted
I	Familiarization of Control System Tool Box, Analysis of simple linear system models in MATLAB	2
II	Analysis of typical systems like DC Motor Control, Satellite control system, Torsional mechanical system etc. using MATLAB and SIMULINK.	2
III	Lag Compensator design based on time domain approach.	2
IV	Lead compensator design based on time domain approach	2
V	Lag lead compensator design based on time domain approach	2
VI	Lag compensator design based on frequency domain approach	2

VII	Lead compensator design based on frequency domain approach	2
VIII	Lag lead compensator design based on frequency domain approach	2
IX	Design and realization of state feedback control for a given system.	2
X	Design and realization of full order observer for a given system.	2
XI	Design and realization of a closed loop reduced observer for a given system to Implement a state feedback controller.	2
XII	Assignment: To analyze a given practical system model and design and realize a suitable controller for the system.	2
XIII	Illustration Numerical methods like Runga-Kutta, Euler method and Newton - Raphson method in MATLAB	2
INTERNAL EXAMINATION		

SEMESTER – II

Syllabus and Course Plan

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6102	Optimal Control Theory	3-1-0	4	2015

Course Objectives

1. To choose a suitable performance measure to meet the specific requirements for a typical optimal control problem.
2. To equip the students to formulate optimal control problems.
3. Familiarize the concepts of calculus of variations.
4. To analyse the physical system and to design the controller by optimizing the suitable performance criteria by satisfying the constraints over the state and inputs.

Syllabus

Optimal control problems; Mathematical models; Selection of performance measures; Constraints; Calculus of Variations; Basic concepts; Variation of a functional, extremals; Fundamental theorem in calculus of variation; Euler equation; Piecewise smooth extremals; Pontryagin's Minimum Principle; Minimum time, Minimum control effort, Minimum fuel, Minimum energy problems, Singular Intervals. Dynamic Programming; Optimal control law; Principle of optimality; Linear Regulator Problems; Stability

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Formulate the optimal controller design problem.
2. Apply constrained optimization to various physical systems.
3. Implement optimal control algorithms to track the response of the system through a predefined trajectory

References

1. Donald E. Kirk, Optimal Control Theory - An Introduction, Prentice-Hall Inc. Englewood Cliffs, New Jersey, 1970.
2. Brian D. O. Anderson, John B. Moore, Optimal Control-Linear Quadratic Methods, Prentice-Hall Inc., New Delhi, 1991.
3. Athans M. and P. L. Falb, Optimal control- An Introduction to the Theory and its Applications, McGraw Hill Inc., New York, 1966.
4. Sage A. P., Optimum Systems Control, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1968.
5. D. S. Naidu, Optimal Control Systems, CRC Press, New York Washington D. C., 2003.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**% of Marks in End-Semester Examination**
I	Optimal control problems - mathematical models-selection of performance measures, constraints- classification of problem constraints - problem formulation – examples, comparison with static optimization. Calculus of Variations: basic concepts - variation of a functional - extremals – fundamental theorem in calculus of variation - Euler equation	7	15
II	Piecewise smooth extremals, constrained minimization of functionals – Point constraints, differential equation constraints, isoperimetric constraints, Hamiltonian -necessary conditions for optimal control, problems with different boundary conditions	7	15
FIRST INTERNAL EXAM			
III	Pontryagin's Minimum Principle, State variable inequality constraints, the set of reachable states, Minimum time problems-bang bang control, Minimum Control Effort problem.	10	15
IV	Minimum Fuel problems-bang off bang control, Minimum Energy problems, Singular intervals in optimal control problems, Effects of Singular Intervals, Numerical Examples.	12	15
SECOND INTERNAL EXAM			
V	Dynamic Programming - Optimal control law-principle of optimality - Application to decision making problems-routing problem-application to typical optimal control problem, Interpolation, recurrence relation in dynamic programming	10	20
VI	Hamilton Jacobi Bellman equation- Standard Regulator Problem: Continuous linear regulator Problems – Discrete Linear Regulator Problems –Finite time Vs Infinite time regulator Problems – Stability	10	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6104	Nonlinear Control Systems	3-0-0	3	2015

Course Objectives

1. To study the essentials of nonlinear control.
2. To extend the analysis techniques for classical control theory to nonlinear system.
3. To analyse the physical system with inherent non-linearity for stability and performance.
4. To provide the necessary methods for designing controllers for Non-linear systems

Syllabus

Introduction to nonlinear dynamical systems' features, , Existence of Limit Cycles; Numerical construction of Phase Portraits by isocline method; Classification of Equilibrium Points; Existence and uniqueness of solutions, Lipschitz condition,Lyapunov Theory; Invariance Principle; *L* Stability, Absolute Stability, Azermanns and Kalman's Conjecture; Lure's Problem; Kalman-Yakubovich-Popov Lemma; Circle Criterion; Popov's Stability Criterion; Design via Linearization; Gain Scheduling Feedback Linearization; Back Stepping.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Gain insight into the complexity of nonlinear systems.
2. Apply methods of characterizing and understanding the behaviour of systems that can be described by nonlinear ordinary differential equations.
3. Use tools including graphical and analytical for analysis of nonlinear control systems.
4. Use a complete treatment of design concepts for linearization via feedback.
5. Demonstrate an ability to interact and communicate effectively with peers.

REFERNCES

1. Hassan K. Khalil, "*Nonlinear Systems*", McMillan Publishing Company, NJ, 2004.
2. John E. Gibson, "*Nonlinear Automatic Control*", McGraw-Hill, New York.
3. Jean-Jacques E. Slotine and Weiping Li, "*Applied Nonlinear Control*", Prentice-Hall,
4. NJ, 1991.
5. M. Vidyasagar, "*Nonlinear Systems Analysis*", Prentice-Hall, India, 1991,
6. ShankarSastry, "*Nonlinear System Analysis, Stability and Control*", Springer, 1999.
7. AlbertoIsidori, "*Nonlinear Control Systems: An Introduction*", Springer-Verlag, 1985.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Introduction to nonlinear dynamical systems' features, Nonlinear models and nonlinear phenomena, Examples, Multiple equilibria, Qualitative behaviour near equilibrium points, Existence of Limit Cycles; Numerical construction of Phase Portraits using Isocline method; Classification of Equilibrium Points.	6	15
II	Existence and uniqueness of solutions, Lipschitz condition, Continuous dependence on Initial conditions and parameters, Theorems on continuity of solutions and proof.	7	15
FIRST INTERNAL EXAM			
III	Lyapunov stability: Stability in the Sense of Lyapunov, Lyapunov Stability Theorem and proof, Invariance Principle, Analysis of Instability, Linear systems and linearization, Construction of Lyapunov function for non linear systems: Variable Gradient Method	7	15
IV	*L* stability, Aizermanns and Kalman's conjecture, Lure's Problem, Absolute Stability-Kalman- Yakubovich-Popov Lemma. Circle Criterion Popov's stability Criterion.	8	15
SECOND INTERNAL EXAM			
V	Non-linear control system design: Stabilization via Linearization, Integral Control via Linearization, Gain Scheduling.	7	20
VI	Feedback Linearization, Motivation, Input-Output Linearization, State Feedback Control, Back Stepping.	7	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6112	Process Control & Industrial Automation	**3-0-0**	**3**	**2015**

Course Objectives

1. To understand physical process control problems
2. To provide knowledge on the industrial application of PID controllers
3. To analyse different control structures used in process control
4. To understand the field of industrial automation

Syllabus

Introduction to process dynamics; process control dynamics; different control modes and tuning; Advanced process control techniques for both linear and nonlinear systems; Control using hierarchical; MPC and Internal mode architectures; Statistical process control; Digital controllers; Implementation of PID. Introduction to SCADA; PLC; Interfacing of PLC; Industrial application of PLC; Distributed control systems; Digital gate logic; PLC Ladder logic; Introduction to IEC 61511/61508

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Model a process control system and understand its dynamics
2. Able to recommend different control architectures needed in the industry
3. Design and tune PID controllers for a given system.
4. Hands on training on latest industrial automation tools such as SCADA, PLC..

References

1. Luyben W., 'Process Modelling, Simulation and Control for Chemical Engineers,' Mc-Graw Hill, 2/e.
2. Donald R. Coughanowr , 'Process Systems Analysis And Control, ' Mc-Graw hill, 3/e.
3. G. Liptak, 'Handbook of Process Control,' 1996
4. George Stephanopoulos, 'Chemical Process Control,' Prentice Hall of India.
5. Enrique Mandado, Jorge Marcos, Serrafin A Perrez, 'Programmable Logic Devices and Logic Controllers,' Prentice Hall, 1996.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**% of Marks in End-Semester Examination**
I	Introduction to process dynamics- Physical examples of first order process, first order systems in series, dynamic behavior of first and second order systems, Control valves and transmission lines, dynamics and control of heat exchangers.	5	15%
II	Process control dynamics- level control, flow control, stability and control of chemical reactors, different control modes and tuning-ON/OFF, P, PI, PD, PID. Ziegler Nichols self tuning methods.	7	15%
FIRST INTERNAL EXAM			
III	Advanced process control techniques for both linear and nonlinear systems- Feed forward control, cascade control, ratio control, adaptive control, override control, control of nonlinear process with delay, Hierarchical control, internal mode control.	9	15%
IV	MPC, Statistical process control. Digital controllers, effect of sampling, Implementation of PID-stability and tuning, digital feed forward control	7	15%
SECOND INTERNAL EXAM			
V	Introduction to SCADA- SCADA Systems, SCADA Architecture; monolithic, distributed and network, PLC-combinational and sequential logic controllers, system integration with PLCs and computers, application in industry. Distributed control systems-PC based control	7	20%
VI	Programming ON/OFF inputs to produce ON/OFF outputs, Relation of digital gate logic to contact/coil logic, Digital gate logic, PLC Ladder logic, Introduction to IEC 61511/61508 and the safety cycle.	7	20%
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6114	Adaptive Control	3-0-0	3	2015

Course Objectives

1. Inculcate conceptual understanding of adaptive control
2. Provide knowledge on various adaptive schemes, with a basic understanding on closed loop system stability and implementation issues
3. Develop ability to design suitable stable adaptive scheme to meet the performance objectives even in the presence of disturbances and changing operating conditions
4. Design model reference adaptive control system considering matched structured uncertainties
5. Identify the need and apply appropriate adaptive control design technique to real-time systems

Syllabus

Adaptive Control, Adaptive Schemes, Adaptive Control Problem; Applications, Regression Models, Recursive Least Squares, Real-Time Parameter Estimation, Direct and Indirect Self-Tuning Regulators Pole Placement Design, MDPP, Model Reference Adaptive Systems, MIT Rule, Design of MRAS Using Lyapunov Theory, Relations between MRAS and STR, Adaptive Feedback Linearization, Adaptive Back Stepping, Gain Scheduling, Design of Gain-Scheduling Controllers, Nonlinear Transformations. Practical Issues and Implementation, Operational Issues, Case Study

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Formulate adaptive control design problem
2. Identify suitable adaptive controller for a given system with uncertain parameters
3. Apply adaptive design techniques to real-time systems whose parameters change during operation.
4. Implement adaptive control schemes to meet the performance objectives in challenging situations.
5.

References

1. Karl Johan Astrom and BjomWittenmark, 'Adaptive Control' , Addison Wesley,2003
2. Shankar Sastry, 'Adaptive Control', PHI (Eastern Economy Edition), 1989
3. Karl Johan Astrom, 'Adaptive Control', Pearson Education, 2001
4. Petros A Loannou, Jing, 'Robust Adaptive Control', Prentice-Hall, 1995
5. Eykhoff P, 'System Identification: Parameter and State Estimation', 1974
6. Ljung, 'System Identification Theory for the User', Prentice-Hall, 1987

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Introduction: Adaptive Control, effects of process variation - Adaptive Schemes - Adaptive Control problem - Applications - Real-Time Parameter Estimation: Introduction - Regression Models - Recursive Least Squares - Exponential Forgetting - Estimating Parameters in Dynamical Systems - Experimental Conditions – Loss of identifiability due to feedback	7	15%
II	Deterministic Self-Tuning Regulators: Introduction - Pole Placement Design, MDPP - Design of Indirect Self-tuning Regulators - Continuous Time Self-tuners - Direct Self-tuning Regulators - Properties of Direct Self-tuners - Disturbances with Known Characteristics, Case Study	8	15%
FIRST INTERNAL EXAM			
III	Model Reference Adaptive Systems: Introduction - MIT Rule - Significance of Adaptation Gain - Lyapunov Stability Theory - Design of MRAS Using Lyapunov Theory - Adaptation of a Feedforward Gain - Applications to Adaptive Control, Case Study	8	15%
IV	Relations between MRAS and STR - Nonlinear Systems - Feedback Linearization - Adaptive Feedback Linearization - Back Stepping - Adaptive Back Stepping, Case Study	7	15%
SECOND INTERNAL EXAM			
V	Gain Scheduling: Introduction - Principle - Design of Gain-Scheduling controllers - Nonlinear Transformations - Applications of Gain Scheduling, Case Study	6	20%
VI	Practical Issues and Implementation - Controller Implementation - Computational Delay - Sampling and Pre- and Post Filtering - Controller Windup - Estimator Implementation - Operational Issues	6	20%
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6412	**New And Renewable Sources Of Energy**	**3-0-0**	**3**	**2015**

Course Objectives

This subject provides sufficient knowledge about the promising new and renewable sources of energy so as to equip students capable of working with projects related to its aim to take up research work in connected areas.

Syllabus

Solar energy- Solar radiation measurements- Applications of solar energy- Energy from oceans- Tidal energy- Wind energy-Small Hydro Power (SHP) Stations- Biomass and bio-fuels- Geothermal energy-Power from satellite stations- Hydrogen energy

Expected Outcome

Upon successful completion of this course, students will be able to design and analyses theperformance of small isolated renewable energy sources.

References

1. John W. Twidell, Anthony D Weir, *"Renewable Energy Resources"*, English Language Book
2. Society (ELBS), 1996
3. Godfrey Boyl, *"Renewable Energy -Power for Sustainable Future"*, Oxford University Press, 1996
4. S. A. Abbasi, NaseemaAbbasi, *"Renewable energy sources and their environmental impact"*, Prentice-Hall of India, 2001
5. G. D. Rai, *"Non-conventional energy sources"*, Khanna Publishers, 2008
6. G. D. Rai, *"Solar energy utilization"*, Khanna Publishers, 2000
7. S. L. Sah, *"Renewable and novel energy sources"*, M.I. Publications, 1995
8. S. Rao and B. B. Parulekar, *"Energy Technology"*, Khanna Publishers, 1999

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination

I	Direct solar energy-The sun as a perennial source of energy; flow of energy in the universe and the cycle of matter in the human ecosystem; direct solar energy utilization	3	15%
	Solar radiation measurements, solar radiation data, estimation of average solar radiation	4	
II	Applications of solar energy – water heating systems, space heating and cooling of buildings, solar cooking, solar ponds, solar green houses, solar thermal electric systems; solar photovoltaic power generation; solar production of hydrogen.	6	15%
FIRST INTERNAL EXAM			
III	Energy from oceans-Wave energy generation - potential and kinetic energy from waves; wave energy conversion devices	3	15%
	Tidal energy - basic principles; tidal power generation systems;- Ocean thermal energy conversion (OTEC); methods of ocean thermal electric power generation	4	
IV	Wind energy - basic principles of wind energy conversion; design of windmills; wind data and energy estimation	4	15%
	Site selection considerations. Types of wind machines-Horizontal axis and Vertical axis machines	4	
SECOND INTERNAL EXAM			
V	Classification of small hydro power (SHP) stations; description of basic civil works design considerations;Turbines and generators for SHP; advantages and limitations.	4	20%
	Biomass and bio-fuels; energy plantation; biogas generation; types of biogas plants; applications of biogas; energy from wastes, Chemical energy sources-Types of fuel cells-Batteries	3	
VI	Geothermal energy- Origin and nature of geothermal energy; classification of geothermal resources; schematic of geothermal power plants; operational and environmental problems;	4	20%
	Power from satellite stations, Hydrogen energy –production-storage-transportation –utilization, nuclear fusion energy, cold fusion	3	
END SEMESTER EXAM			

Course No	Course Name	L-T-P	Credits	Year of Introduction
01EE6314	PWM Converters and Applications	3-0-0	3	2015

Course Objectives:

1. To learn about different switches and implementation of various switch scheme using available power semiconductor devices.
2. To learn about different topologies of rectifiers and inverters.
3. To study about the modulation methods in three phase inverters.
4. To learn about the space vector PWM
5. To study about the Synchronised and non-synchronised PWM-Multilevel Converters
6. To learn about different topologies of multilevel converters and their modulation techniques
7. To familiarize about the various application of PWM converters
8. To study about the current control in PWM inverters
9. To learn about the harmonic elimination in PWM current source inverters
10. To analyse and develop selective harmonic elimination strategies for converters.
11. To develop control strategies for PWM converters with applications to drives, active front-end rectifier and shunt active filters.
12. To provide an opportunity to implement space vector modulation for CSI.

Syllabus

Use of Single-Pole-Double-Throw Single-Pole-Multi-Throw switches to describe Converter Topologies: Implementation of various switch schemes using available power semiconductor devices. Topologies of Inverters and Rectifiers--relation between Pole voltages, Line voltages and Line-to-load neutral voltages in multi-phase two-level inverters- Basic modulation methods--duty ratio--sine-triangle modulation--implementation of unipolar and bipolar modulation--three-phase inverters- Space vector PWM - conventional sequence- 30 degree and 60 degree bus clamped PWM—relation between sine-triangle and space vector PWM--dc bus utilisation of SPWM and SVPWM. Synchronised and non-synchronised PWM-Multilevel Converters: Topologies. Neutral Point Clamped and Flying Capacitor Topologies. Cascaded Multilevel Inverters-Multilevel Converters Modulation - Conventional Space Vector Modulation for 3-level inverters. Applications of PWM converters-Active front end rectifier--vector control of front-end rectifier- Control of Shunt active filter - Current Control in inverters: Current controlled PWM VSI -Hysteresis Control - fixed band and variable band hysteresis. Selective Harmonic Elimination-Derivation of simultaneous transcendental equations for elimination of harmonics-PWM Current Source Inverters--Current Space Vectors- Space Vector Modulation of CSI-Application of CSI in high-power drives-Fundamental principles of Hybrid schemes with CSI and VSI

Expected Outcome:

Upon successful completion of this course, students will be able to:

1. Represent complex power converters using simple switch elements and analyse their steady state behaviour.

2. Create simulation models of advanced PWM converters including multilevel converters.
3. Design and implement modulation/control strategies such as sine-triangle PWM, Space Vector PWM and hysteresis control.
4. Develop control strategies for PWM converters with applications to drives, active front-end rectifier and shunt active filters.
5. Analyse and develop selective harmonic elimination strategies for converters.
6. Implement space vector modulation for CSI.

References:

1. Joseph Vithayathil, "Power Electronics", McGrawhill
2. Bin Wu, "High Power Converters and AC Drives,"
3. Ned Mohan, *et. al.,* "Power Electronics: Converters, Design and Applications," Wiley
4. L. Umanand, "Power Electronics: Essentials and Applications," Wiley, 2009.
5. Werner Leonhard, "Control of Electrical Drives,", 3/e., Springer
6. Bimal K. Bose, "Modern Power Electronics and AC Drives," Prentice Hall
7. J.Holtz, "Pulsewidth modulation - a survey", IEEE Trans. IE, Vol. IE-39(5), 1992, pp.
8. J.Holtz, "Pulsewidth modulation for electronic power conversion", Proc. IEEE, Vol.82(8), 1994, pp. 1194-1214.
9. V.T.Ranganathan, "Space vector modulation - a status review", Sadhana, Vol. 22(6),1997, pp. 675-688.
10. L.M.Tolbert, F.Z.Peng and T.G.Habelter, "Multilevel inverters for large electric drives,IEEE Transactions on Industry Applications, Vol.35, No.1, pp. 36-44, Jan./Feb. 1999.
11. SangshinKwak, Hamid A. Toliyat, "A Hybrid Solution for Load-Commutated-Inverter-Fed Induction Motor Drives," IEEE Trans. on Industry Applications, vol. 41, no. 1,January/February 2005.
12. SangshinKwak, Hamid A. Toliyat, "A Hybrid Converter System for High-PerformanceLarge Induction Motor Drives," IEEE Trans. on Energy Conversion, vol. 20, no. 3,September 2005.
13. SangshinKwak, Hamid A. Toliyat, "A Current Source Inverter With Advanced ExternalCircuit and Control Method," IEEE Trans. on Industry Applications, vol. 42, no. 6,November/December 2006.
14. A.R. Beig, and V. T. Ranganathan, "A novel CSI-fed Induction Motor Drive," IEEE Trans. on Power Electronics, vol. 21, no. 4, July 2006.
15. H.Stemmler, "High-power industrial drives," Proc. IEEE, Vol. 82(8), 1994, pp. 1266-1286.

COURSE PLAN

Module	**Course description**	**Hours**	**End semester exam % marks**

1	Use of Single-Pole-Double-Throw Single-Pole-Multi-Throw switches to describe Converter Topologies: Basic switch constraints-Implementation of various switch schemes using available power semiconductor devices. Topologies of Inverters and Rectifiers--relation between Pole voltages, Line voltages and Line-to-load neutral voltages in multi-phase two-level inverters	7	15%
2	Basic modulation methods--duty ratio--sine-triangle modulation--implementation of unipolar and bipolar modulation--three-phase inverters- Harmonic performance of Unipolar and Bipolar modulation schemes in single phase and three phase inverters-linear modulation and over modulation	8	15%
	First Internal Exam		
3	Space vector PWM - conventional sequence- 30 degree and 60 degree bus clamped PWM--relation between sine-triangle and space vector PWM-dc bus utilisation of SPWM and SVPWM. Over modulation in SVPWM-Over modulation zones. Synchronised and non-synchronised PWM	8	20%
4	Multilevel Converters: Topologies. Neutral Point Clamped and Flying Capacitor Topologies. Cascaded Multilevel Inverters. Multilevel Converters Modulation -Carrier based approach-Conventional Space Vector Modulation for 3-level inverters.	7	20%
	Second Internal Exam		
5	Applications of PWM converters--Active front end rectifier--vector control of front-end rectifier-Control of Shunt active filter- PWM converters in AC drives-Current Control in inverters: Current controlled PWM VSI -Hysteresis Control -fixed band and variable band hysteresis.	6	15%
6	Selective Harmonic Elimination-Derivation of simultaneous transcendental equations for elimination of harmonics PWM Current Source Inverters--Current Space Vectors- Space Vector Modulation of CSI--Application of CSI in high-power drives-Fundamental principles of Hybrid schemes with CSI and VSI.	6	15%
	End Semester Exam		

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6116	**Sliding Mode Control**	**3-0-0**	**3**	**2015**

Course Objectives

1. To familiarize the students with the methodology for the design and implementation of sliding mode controllers for any uncertain plant.
2. To design higher order sliding mode controllers and observers.

Syllabus

Introduction to variable structure systems; Mathematical background; existence conditions of sliding mode; concept of a manifold; sliding surface; sliding mode motion and sliding mode control; Method of equivalent control Chattering Problem; Approaches of sliding hyper plane design; Discrete-time sliding mode control; Multi-rate output feedback; Discrete-time sliding mode control based on multi-rate output feedback techniques; Sliding mode observers; Introduction to Higher Order Sliding Mode (HOSM) control and observation; Twisting controller; Super Twisting controller; Lyapunov based sliding mode control; Super twisting based observers and differentiators

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Design robust nonlinear sliding mode controllers for any uncertain plant.
2. Design higher order sliding mode controllers and observers .

References

1. C. Edwards and S. K. Spurgeon, Sliding mode control: Theory and applications. Taylor and Francis; 1998.
2. V. I. Utkin, Sliding Modes in Control Optimization. New York: Springer-Verlag; 1992.
3. J. Y. Hung, W. Gao and J. C. Hung, "Variable structure control: A survey;" IEEE Transactions on Automatic Control; vol. 40; 1993.
4. Y. W. WeibingGao and A. Homaifa, "Discrete-time variable structure control systems;" IEEE Transactions on Ind. Electronics; vol. 42; no. 2; pp. 117–122; 1995.
5. B. Bandyopadhyay and S. Janardhanan, Discrete-time Sliding Mode Control: A Multi-rate Output Feedback Approach. Lecture Notes in Control and Information Sciences; Berlin: Springer-Verlag; 2005; no. 323.
6. K. Abidi, J. X. Xu, and Y. Xinghuo, "On the discrete-time integral sliding-mode control;" IEEE Transactions on Automatic Control; vol. 52; no. 4; pp. 709–715; 2007

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Introduction to variable structure systems; definition of variable structure and sliding mode; examples of dynamic systems with sliding modes. Mathematical background: differential equations with discontinuous right-hand sides; solutions in Filippov sense ; existence conditions of sliding mode; concept of a manifold; sliding surface; sliding mode motion and sliding mode control.	6	15%
II	Regular form Approach-Pole placement and LQR method. Properties of sliding mode motion. Reaching laws; methods of equivalent control Chattering Problem. Approaches of sliding hyper plane design	9	15%
FIRST INTERNAL EXAM			
III	Discrete-time sliding mode control: definitions; design methods; reaching laws for discrete-time sliding mode control; Switching and non-switching based discrete-time sliding mode control.	9	15%
IV	Discrete-time sliding mode control based on Multi-rate Output Feedback techniques. Terminal Sliding mode control; Integral Sliding mode control - Design of sliding surface and control law development	6	15%
SECOND INTERNAL EXAM			
V	Sliding mode observers - Need of sliding mode observers; Design of sliding mode observers; design examples.	6	20%
VI	Introduction to Higher Order Sliding Mode (HOSM) control and observation. Twisting controller. Super Twisting controller. Lyapunov based sliding mode control. Super twisting based observers and differentiators. Applications of Sliding mode controllers.	6	20%
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6118	Stochastic Control	**3-0-0**	**3**	**2015**

Course Objectives

1. To design suitable performance measure to meet the specification requirements.
2. To analyse the physical system and design the structure of controller by optimizing the suitable performance criteria.
3. To apply the design algorithms to various physical systems with stochastic parameters.
4. Provides a solid foundation on modeling and analysis of system with stochastic parameter.

Syllabus

Random Variables; Probability Distribution; Expectations; Functions of Random Variables; Correlation and auto correlation; Special stochastic Processes; Stochastic State Models; Continuous Time Systems; Stochastic Integrals; Modelling of physical process by stochastic differential equations; Analysis of dynamical systems with Stochastic inputs; Spectral Factorization of Discrete Time Processes; Analysis of Continuous Time Systems with Stochastic input.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Analyse the stability and performance of the systems with stochastic parameters.
2. Identify suitable estimation algorithm for stochastic systems.
3. Formulate and design suitable control structure of stochastic system model.
4. Implement optimal control algorithms to achieve specified performance for systems with stochastic parameters.

References

1. Jason L. Speyer and Walter H. Chung, "Stochastic Process, Estimation and Control," Siam Philadelphia, 2008.
2. Karl J. Åström, "Introduction to Stochastic Control Theory," Academic Press, New York and London, 1970.
3. KaddourNajim, Enso Ikonen and Ait-KadiDaoud, "Stochastic Processes Estimation, Optimization & Analysis," Kogan Page Science, London and Sterling, 2004.
4. Birkhäuser, "Stochastic Switching Systems Analysis and Design," Library of Congress Cataloguing-in-Publication Data, United States of America, 2006.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	. Introduction: Random Variables – Probability Distribution Function – Probability Density Function – Functions of Random Variables	6	15
II	Expectations and Moments of Random Variables – Conditional Expectations and Conditional Probabilities – Correlation – Auto Co-relation - Concept of Special Stochastic Processes – Covariance Function – Spectral Density.	9	15
FIRST INTERNAL EXAM			
III	Stochastic State Models: Discrete Time Systems – Solution of Stochastic Difference Equations – Continuous Time Systems	9	15
IV	Stochastic Integrals – Linear Stochastic Differential Equations – ITO Differentiation Rule – Modelling of Physical Process by Stochastic Differential Equations.	6	15
SECOND INTERNAL EXAM			
V	Analysis of Dynamical Systems with Stochastic Inputs: Discrete Time Systems – Spectral Factorization of Discrete Time Processes	6	20
VI	Analysis of Continuous Time Systems with Stochastic Input – Spectral Factorization of Continuous Time Process.	6	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6122	Industrial Data Networks	3-0-0	3	2015

Course Objectives

1. To understand data networks and internet configuration
2. To have adequate knowledge in various communication protocols
3. To understand industrial data networks

Syllabus

Data Network Fundamentals; Data link control protocol; Bridges, Routers, Gateways; Standard ETHERNET and ARCNET configuration special requirement for networks used for control; Evolution of signal standard; HART communication protocol; Communication modes; General Fieldbus; OLE for Process Control; MODBUS protocol structure; Profibus protocol stack; Profibus communication model - communication objects; foundation field bus; Industrial Ethernet and Wireless Communication; Radio and wireless communication.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Analyse the functionalities of various industrial Communication Protocols
2. Implement and analyse industrial Ethernet and wireless communication modules

References

1. Steve Mackay, Edwin Wrijut, Deon Reynders and John Park, 'Practical Industrial Data Networks Design, Installation and Troubleshooting', Newnes publication, Elsevier, 1st ed., 2004.
2. William Buchanan 'Computer Busses', CRC Press, 2000.
3. Andrew S. Tanenbaum, 'Modern Operating Systems', Prentice Hall India, 2003
4. Theodore S. Rappaport, 'Wireless Communication: Principles & Practice, 2nd ed., 2001, Prentice Hall of India
5. Willam Stallings, 'Wireless Communication & Networks', 2nd ed., 2005, Prentice Hall of India

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination

I	Data Network Fundamentals: Network hierarchy and switching – Open System Interconnection model of ISO– Data link control protocol: - HDLC – Media access protocol – Command/response – Token passing – CSMA/CD, TCP/IP.	6	15%
II	Bridges – Routers – Gateways –Standard ETHERNET and ARCNET configuration special requirement for networks used for control.	7	15%
FIRST INTERNAL EXAM			
III	Hart, Fieldbus, Modbus and Profibus PA/DP/FMS and FF: Introduction - Evolution of signal standard – HART communication protocol – Communication modes – HART networks - HART commands - HART applications. Fieldbus: Introduction – GeneralFieldbus architecture - Basic requirements of Field bus standard - Fieldbus topology - Interoperability - Interchangeability	9	15%
IV	Introduction to OLE for process control (OPC). MODBUS protocol structure - function codes - troubleshooting Profibus: Introduction - profibus protocol stack – profibus communication model - communication objects – system operation - troubleshooting - review of foundation field bus.	7	15%
SECOND INTERNAL EXAM			
V	Industrial Ethernet and Wireless Communication: Industrial Ethernet: Introduction - 10Mbps Ethernet, 100Mbps Ethernet.	7	20%
VI	Radio and wireless communication: Introduction - components of radio link - the radio spectrum and frequency allocation - radio modems.	6	20%
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6432	Sustainable and Translational Engineering	3-0-0	3	2015

Course Objectives

The purpose of this course is:-

1. To bring in to focus the basics aspects of sustainable development.
2. To have a general understanding on global environmental issues and the different aspects involved in Green Technology.

Syllabus

History and emergence of the concept of Sustainable Development; Economic dimensions, Environmental dimension; Framework for sustainability, assessment of sustainable erformance; Industrialization, Globalization and Environment; Global environmental issues; Waste land reclamation, Resource degradation, carbon credits and Carbon trading – Carbon footprint; Energy, Conventional and renewable sources, Green buildings, green materials, Technology and sustainable development, Sustainable urbanization, Industrial Ecology.

Expected Outcome

The student will be able to

1. Understand the concept of sustainable development
2. To have an insight in to global environmental issues
3. Understand the different aspects of green Technology

References

1. Kurian Joseph & R. Nagendran' Essential Environmental studies'. Pearson education, New Delhi, 2004.
2. S.C Bhatia, Environmental Pollution and Control in Chemical Process Industries, Khanna Publishers, Delhi, 2005.
3. Kirkby, J.O' Keefe, P. and Timberlake, Sustainable Development, Earthscan Publication, London, 1996.
4. Mackenthun, K.M., Basic Concepts in Environmental Management, Lewis Publication, London, 1998.
5. S.S Purohit ,Green Technology-An approach for sustainable environment, Agrobios publication, India, 2008.
6. Twidell, J. W. and Weir, A. D., Renewable Energy Resources, English Language Book Society (ELBS).

Course Plan			
Module	**Contents**	**Hours Allotted**	**% of Marks in End Semester Examination**
I	History and emergence of the concept of Sustainable Development – Framework of Sustainability, economic dimensions- environmental dimension	7	15
II	Framework for achieving sustainability, assessment of sustainable performance- Industrialization – Globalization and Environment	7	15
First Internal Exam			
III	Global environmental issues: - desertification– green house gases- greenhouse effect, ozone layer depletion- global warming–acid rain– deforestation.	7	15
IV	Waste land reclamation-Resource degradation, carbon credits and Carbon trading-International summits- conventions-agreements-trans boundary issues- Carbon footprint	7	15
Second Internal Exam			
V	Energy sources: Basic concepts- Conventional and non-conventional, solar energy, Fuel cells, Wind energy, Small hydro plants, bio-fuels, Energy derived from oceans, Geothermal energy.	7	20
VI	Green buildings, Sustainable cities, Sustainable Urbanisation Sustainable transport, Green Engineering, Industrial Ecology, Industrial symbiosis.	7	20
End Semester Exam			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6124	Robotics and Control	**3-0-0**	**3**	**2015**

Course Objectives

1. To familiarize students with robot classifications and configurations.
2. To acquaint the students with Forward Kinematics and Inverse Kinematics, Trajectory planning, dynamic modeling, control and applications of robots.
3. To acquaint the students with mobile robot locomotion and kinematics, environment perception, localization, mapping and navigation of mobile robots.

Syllabus

Introduction to Robotics; Co-ordinate frames; Kinematic analysis of robots (DOF≤3); Inverse kinematics of robots (DOF≤3);Basic study of other robots up to 6 DOF; Trajectory planning; Manipulator Dynamics; Robot Model; Control schemes; Robot vision; Applications; Autonomous mobile robots; Wheeled mobile robots; Basics of Legged mobile robots, Kinematic Models; Sensors and beacons.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. To obtain kinematic model of a robot (DOF ≤3).
2. To develop dynamic model of a robot (DOF ≤3).
3. To design a linear / nonlinear controller for a robot.
4. To identify the various types of sensors and recognize common uses.
5. To choose a sensor for a robot depending on the application.
6. To design a simple mobile robot for accomplishing a task autonomously.

References

1. 1. Robert J Schilling, “Fundamentals of Robotics-Analysis and Control”, Pearson Education, Asia.
2. R. K. Mittal and J. Nagrath, “Robotics and Control”, Tata McGraw-Hill Education.
3. R. Siegwart, I. Nourbakhsh, D. Scaramuzza, “ Introduction to Autonomous Robots”, Intelligent Robotics and Autonomous Agents series, The MIT Press, Massachusetts Institute of Technology, Cambridge, Massachusetts.
4. Ashitava Ghosal, “Robotics-Fundamental concepts and analysis”, Oxford University press.
5. Janakiraman P A, "Robotics and Image Processing", Tata McGraw Hill. New Delhi, 1995
6. S R Deb, "Robotics Technology and Flexible Automation", Tata McGraw Hill, New Delhi
7. Peter Corke, “Robotics, Vision and Control – Fundamental Algorithms in MATLAB”, Springer Tracts in Advanced Robotics, volume 73.
8. Lorenzo Sciavicco& Bruno Siciliano, “Modeling and Control of Robot manipulator”, The McGraw Hill Companies.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Introduction to Robotics, classification, specifications, Work envelopes of different robots, notations, Co-ordinate frames, Rotations, Translations, Homogeneous coordinates, Direct kinematics, The arm equation, Kinematic analysis of robots (DOF≤3)- examples, Inverse kinematics problem, Inverse kinematics of robots (DOF≤3)- examples.	6	15%
II	Basic study of other robots up to 6 DOF, Workspace analysis, Pick and place operation, Tool configuration Jacobianand manipulator Jacobian matrix. Trajectory planning - Joint space and Cartesian space techniques.	9	15%
FIRST INTERNAL EXAM			
III	Manipulator Dynamics-Dynamic models of robots using Lagrange's Equation (DOF≤2), State space model of the robot and the linearized model. The control problem- Linear control Schemes, Single axis PID control, PD gravity control, Nonlinear control Schemes-Computed torque control, Variable Structure control, Force and Impedance control, co-ordinated control.	9	15%
IV	Robot Vision - Image representation, template matching, edge and corner detection, shape analysis, segmentation, perspective transformations, camera calibration, Robotapplications-material handling applications, Machine loading and unloading, spot welding, arc welding, spray painting and technical specifications of the robot used for these applications.	6	15%
SECOND INTERNAL EXAM			
V	Autonomous mobile robots- wheeled mobile robots- types, mobile robot kinematics- kinematic models and constraints, representing robot position, forward kinematic models, carlke mobile robot-Moving to a point, following a line, following a path, moving to a pose, Legged locomotion-Basics.	6	20%
V1	Perception- sensors for mobile robots, Sensor classification, Characterizing sensor performance, Wheel/motor sensors, Heading sensors, Accelerometers, IMU, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors, Basics of mobile robot localization and navigation	6	20%
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6126	**Soft Computing Techniques**	**3-0-0**	**3**	**2015**

Course Objectives

1. To provide concepts of soft computing and design controllers based on ANN and Fuzzy systems.
2. To identify systems using soft computing techniques.
3. To give an exposure to optimization using genetic algorithm.
4. To provide a knowledge on hybrid systems.

Syllabus

Biological foundations; ANN models; Feed Forward Network; Radial Basis Function; Learning process; Supervised and unsupervised learning; Least mean square algorithm; Back propagation algorithm; Applications in pattern recognition and other engineering problems; Case studies; Identification and control of linear and nonlinear systems; Fuzzy set operations; Fuzzy control systems; Classical fuzzy control problems; Genetic Algorithm; Adaptive fuzzy systems; Hybrid Systems; Application of soft computing techniques in physical systems.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. To design a complete feedback system based on ANN or Fuzzy control.
2. To identify systems using soft computing techniques.
3. To use genetic algorithm to find optimal solution to a given problem.
4. To design systems by judiciously choosing hybrid techniques.

REFERENCES

1. J. M. Zurada, Introduction to artificial neural systems, Jaico Publishers, 1992.
2. Simon Haykins, Neural Networks - A comprehensive foundation, Macmillan College, Proc, Con, Inc, New York. 1994.
3. D. Driankov. H. Hellendorn, M. Reinfrank, Fuzzy Control - An Introduction, Narosa Publishing House, New Delhi, 1993.
4. H J Zimmermann, Fuzzy set theory and its applications, 11th ed., Academic Publishers, London.
5. G. J. Klir, Boyuan, Fuzzy sets and fuzzy logic, Prentice Hall of India (P) Ltd, 1997.
6. Stamatios V Kartalopoulos, Understanding neural networks and fuzzy logic basic concepts and applications, Prentice Hall of India (P) Ltd, New Delhi, 2000.
7. Timothy J. Ross, Fuzzy logic with Engineering Applications, McGraw Hill, New York.
8. SuranGoonatilake, SukhdevKhebbal (Eds,), Intelligent hybrid systems, John Wiley & Sons, New York, 1995.
9. Vose Michael D., Simple Genetic Algorithm - Foundations and Theory, Prentice Hall of India.
10. Rajasekaran &Pai, Neural Networks, Fuzzy Logic, and Genetic Algorithms: Synthesis and Applications, Prentice-Hall of India, 2007.
11. J. S. Roger Jang, C. T. Sun and E. Mizutani, Neuro Fuzzy and Soft Computing, prentice Hall inc., New Jersey, 1997.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Biological foundations - ANN models - Types of activation function - Introduction to Network architectures - Multi Layer Feed Forward Network (MLFFN) - Radial Basis Function Network (RBFN) - Recurring Neural Network (RNN).	6	15
II	Learning process : Supervised and unsupervised learning - Error-correction learning - Hebbian learning – Boltzmen learning - Single layer and multilayer perceptrons - Least mean square algorithm – Back propagation algorithm - Applications in pattern recognition, Case studies - Identification and control of linear and nonlinear systems.	9	15
FIRST INTERNAL EXAM			
III	Fuzzy sets: Fuzzy set operations - Properties - Membership functions, Fuzzy to crisp conversion, fuzzification and defuzzification methods, applications in engineering problems.	9	15
IV	Fuzzy control systems: Introduction - simple fuzzy logic controllers with examples - Special forms of fuzzy logic models, classical fuzzy control problems, inverted pendulum, image processing, home heating system, Adaptive fuzzy systems.	6	15
SECOND INTERNAL EXAM			
V	Genetic Algorithm: Introduction - basic concepts of Genetic Algorithm, applications.	6	20
VI	Hybrid Systems: Adaptive Neuro fuzzy Inference System (ANF1S), Neuro –Genetic, Fuzzy-Genetic systems.	6	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6214	**Flight Dynamics and Control**	**3-0-0**	**3**	**2015**

Course Objectives

To give insight into the dynamics, performance and control of aircrafts.

Syllabus

Aircraft Performance, Equation of motion of aircraft-level, un-accelerated flight,take-off performance, landingperformance, absolute and serviceceilings. Aircraft Stability and Control, Aircraft transfer functions, control surface actuator, autopilot, stabilityaugmentation.

Expected Outcome

Upon successful completion of this course, students will be able to develop the point massmodel of aircrafts, understand their dynamics and analyse their performances and stabilityissues.

References

1. John D Anderson Jr, 'Introduction to Flight' McGraw Hill International, 5/e,2005
2. John D. Anderson Jr, 'Fundamentals of Aerodynamics', Me Graw Hill International, 4/e, 2007.
3. Thomas R. Yechout, 'Introduction to Aircraft Flight Mechanics', AIAA Education Series,2003.
4. A.C.Kermode, ''Mechanics of Flight', Pearson Education, 10/e, 2005.
5. John H. Blakelock, 'Automatic Control of Aircraft and Missiles' 2/e, Wiley- Inter Science Publication, John Wiley and Sons, Inc., 1991.
6. Bernard Etkin, 'Dynamics of flight Stability and Control', John Wiley and Sons Inc. 3/e, 1996.
7. Robert C. Nelson, 'Flight Stability and Automatic Control', WCB McGraw-Hill, 2/e, 1998.
8. Louis V. Schmidt, 'Introduction to Aircraft Flight Dynamics' AIAA Education Series, 1997

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Aircraft Performance Drag Polar- Drag polar of vehicles from low speed tohypersonic speed. Equation of motion of aircraft-level, un-accelerated flight	4	15
II	Thrust required for level, un-accelerated flight-thrust available and maximum velocity- power required for level,un-accelerated flight-power available and maximumvelocity- altitude effects on power required and available- numerical problems.	8	15
FIRST INTERNAL EXAM			
III	Rate of climb- gliding flight- time to climb- range and endurance- take-off performance- landing performance- numerical problems	8	15
IV	Turning flight and V-n diagram-wing loading -load factor-absolute and service ceilings.	7	15
SECOND INTERNAL EXAM			
V	Aircraft Stability and Control - Longitudinal and lateral dynamics-stability - conditions for longitudinal static stability-modes of motion: short period-phugoid-spiral divergence-dutch roll-stability derivatives-roll coupling.	7	20
VI	Aircraft transfer functions-control surface actuator - longitudinal autopilots- displacementautopilot- pitch autopilot - block diagrams-root locus- accelerationcontrol systems -lateral autopilots- - attitude control systems – stability augmentation.	8	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6426	Smart Grid Technologies and Applications	**3-0-0**	**3**	**2015**

Course Objectives

Objective of the course is to develop a conceptual basis for Smart Grid and to equip the students with a thorough understanding of various communication technologies and power management issues with smart grid.

Syllabus

Evolution of Electric Grid, Smart meters, Smart Substations, Substation Automation, Smart energy efficient end use devices-Smart distributed energy resources- Energy management-Role of technology in demand response- Demand Side Management; Load Frequency Control (LFC) in Micro Grid System, Advanced metering Infrastructure

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Understand features and scope of smart grid technology.
2. Assess the role of automation in substation.
3. Understand operation and importance of demand side management, voltage and frequency control in smart micro grid

References

1. A Stuart Borlase, "Smart Grids, Infrastructure, Technology and Solutions", CRC Press, 2013
2. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
3. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press
4. James Momoh, "Smart Grid:Fundamentals of Design and Analysis", Wiley, IEEE Press, 2012.
5. A.G. Phadke and J.S. Thorp, "Synchronized Phasor Measurements and their Applications", Springer Edition, 2010.
6. Iqbal Hussein, "*Electric and Hybrid Vehicles: Design Fundamentals*", CRC Press, 2003.
7. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,"Smart Grid: Technology and Applications", Wiley 2012.
8. GautamShroff, Enterprise Cloud Computing Technology Architecture Applications [ISBN: 978-0521137355]

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits	3	15
	Present development & International policies in Smart Grid. Indian Smart Grid. Components and Architecture of Smart Grid Design	4	
II	Introduction to Smart Meters, Real Time Pricing- Models, Smart Appliances, Automatic Meter Reading(AMR), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation.	6	15
FIRST INTERNAL EXAM			
III	Smart Substations, Substation Automation, Introduction to IEC 61850, Feeder Automation. Geographic Information System(GIS)	3	15
	Intelligent Electronic Devices(IED) & their application for monitoring & protection, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).	4	
IV	Smart energy efficient end use devices-Smart distributed energy resources- Energy management-Role of technology in demand response- Demand Side Management	4	15
	Load Curves-Load Shaping Objectives-Methodologies-Barriers. Peak load saving-Constraints-Problem formulation- Case study	4	
SECOND INTERNAL EXAM			
V	Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System	4	20
	Reactive Power Control in Smart Grid.	3	
VI	Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Bluetooth, Zig-Bee, GPS, Wi-Fi, Wi-Max based communication	4	20
	Cloud computing in smart grid. Private, public and Hybrid cloud. Cloud architecture of smart grid.	3	
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6192	Mini Project	0-0-4	2	2015

Course Objectives

To make students

Design and develop a system or application in the area of their specialization.

Approach

The student shall present two seminars and submit a report.The first seminar shall highlight the topic, objectives, methodology, design and expected results. The second seminar is the presentation of the work / hardwareimplementation.

Expected Outcome

Upon successful completion of the miniproject, the student should be able to

1. Identify and solve various problems associated with designing and implementing a system or application.
2. Test the designed system or application.

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE6194	Advanced Control Lab	0-0-2	1	2015

Course Objectives

1. Realize different compensators.
2. Design and implement PID controller and familiarize the role of P, I and D in feedback control.
3. Practice of control system design in inverted pendulum system which is widely used as a benchmark for testing control algorithms.
4. Implementation of real time controller for dynamic systems

Syllabus

Realization of a system transfer function using opamps; Design and realization of compensators for a real time system to meet the given performance specifications; Design and implementation of P, PI and PID Controllers for temperature and level control systems; Closed loop control of DC Motor using MATLAB/Simulink; Nonlinear Relay Control System; Speed and position control of DC Motor; Implementation of digital controller using microprocessor; Closed loop control of a DC motor using microcontroller/ DSP/ PC; design and implementation of controller for practical systems - inverted pendulum system, Twin Rotor MIMO, Mobile Robot.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Get exposure to practical aspects of control systems design.
2. Equip the students to perform system identification (make measurements of a system and determine the transfer function).
3. Acquire an ability to critically analyse different dynamic systems and choose a suitable controller
4. Equip the students to apply the concepts of linear and non-linear theory to the design of dynamic systems.

COURSE PLAN		
Experiment No:	**Title**	**Hours Allotted**
I	Realization of a transfer function using opamps	2
II	Realization of compensators using active networks	2
III	Real Time Liquid Level control Using P, PI and PID Controllers	2
IV	Closed loop control of DC Motor using MATLAB/Simulink	2
V	Design and implementation of a controller for an inverted pendulum system.	2
VI	Zeigler Nichols Tuning of P, PI and PID controller for Temperature Control System	2
VII	Nonlinear Relay Control System	2
VIII	Speed and position control of DC servo motor	2
IX	Implementation of digital controller using microprocessor	2
X	Implementation of closed loop controller for the given DC motor using microcontroller/ DSP controller/ PC	2
XI	Design and implementation of controller for a Twin Rotor MIMO	2
XII	Design and implementation of a tracking controller for a mobile robot	2
INTERNAL EXAMINATION		

SEMESTER – III

Syllabus and Course Plan

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7111	Robust Control	**3-0-0**	**3**	**2015**

Course Objectives

1. To equip students with basic knowledge of robust control of linear dynamic systems
2. To identify sources of uncertainties and also able to model the different uncertainties
3. To analyze the sensitivity analysis of feedback control systems
4. To check robust stability and robust performance using different approaches
5. To equip the students to design H- infinity control problems

Syllabus

Modelling of parametric Uncertain systems; Definition of robust control; classification of uncertainties; shaping the loop gain; Modelling systems with parameter uncertainty; Sensitivity Analysis; Single degree of freedom design structure for SISO and MIMO systems; design of SISO feedback systems for disturbance rejection; design of SISO feedback systems for noise rejection, unmodelled dynamics, combining uncertainties for the design of scalar feedback systems; Boundary crossing theorem; Gamma stability; Schur stability test; Hurwitz stability test, Well-posedness; internal stability; co-prime factorization of plant, co-prime factorization of controller; Robust stability and performance in the H - infinity context; small gain theorem; Stability margins; robust stabilizing controllers; Kharitonov approach for stability; preliminary theorems; LQG methodology; separation principle; Algebraic Riccati Equation; solution of LQG problem; H-infinity optimization techniques; design of H-infinity control problem and solution; selection of weighting functions; Basic concepts of H - infinity and μ – synthesis controllers.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Identify different uncertainties and to model the uncertainties
2. Apply different approaches for analysing robust stability and robust performance
3. Design robust controllers for physical systems and compare with other controllers

References

1. S P Bhattacharya, L H Keel, H Chapellat 'Robust Control: The Parametric Approach', Prentice-Hall, 1995
2. P C Chandrasekharan, Robust Control of Linear Dynamical Systems', Academic Press, 1996
3. Michael Green, David J N Limebeer, Linear Robust Control', Prentice-Hall, 1995
4. Kemin Zhou, Essentials of Robust Control', Prentice-Hall, 1998
5. SigurdSkogestad and Ian Postewaite, Muti-variable Feedback Design (Second Edition), John Wiley, 2005
6. Pierre R. Belanger, Control Engineering : A modern Approach, Saunders College Publishing, 1995

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	**Modelling of parametric Uncertain systems:** Definition of robust control-classification of robust control-elements of robust control theory-modelling design objectives and specifications – classification of uncertainties- additive and multiplicative perturbations –plant - controller configuration- shaping the loop gain. Modeling systems with parameter uncertainty- general concepts.	7	15
II	**Sensitivity Analysis**: Single degree of freedom design structure for SISO and MIMO systems- design of SISO feedback systems for disturbance rejection - design of SISO feedback systems for noise rejection - design of SISO feedback systems with un-modelled dynamics – combining uncertainties for the design of scalar feedback systems.	8	15
FIRST INTERNAL EXAM			
III	Boundary crossing theorem-stability - Gamma stability boundaries-Gamma stability radius-Schur stability test-Hurwitz stability test, Well-posedness, internal stability, parameterization approach, co-prime factorization of plant, co-prime factorization of controller - Robust stability in the H - infinity context, robust performance in the H-infinity context, robust stability and performance under perturbations, small gain theorem.	9	15
IV	Different Stability margins-margins, robust stabilizing controllers-stabilizing P controllers-stabilizing PI controllers - stabilizing PID controllers, Kharitonov approach for stability – preliminary theorems – Kharitonov theorem - control design using Kharitonov theorem.	6	15
SECOND INTERNAL EXAM			
V	LQG methodology-separation principle-Algebraic Riccati Equation-solution of LQG problem-robustness properties of the LQG solution.	6	20
VI	H_∞optimization techniques-state space formulation H_∞control problem and solution – selection of weighting functions – general H_∞Control algorithm - *Basic concepts of* H_∞*and* μ *– synthesis controllers*	6	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7113	Advanced Instrumentation	3-0-0	3	2015

Course Objectives

To impart principles of different measurement systems and methods of modern instrumentation.

Syllabus

Generalized performance characteristics of instruments, General concept of transfer function, Dynamic response and frequency response studies, Response of a general form of instrument, Plant level automation, Petrinet models, Sensors, Virtual instrumentation, VI programming techniques.

Expected Outcome

Upon successful completion of this course, students will be able to:

1 By the end of the course the student will be able to identify the performance of different measurement systems and apply it for different control systems.

2 Students will also get a good idea of the virtual instrumentation which is an emerging technology.

References

1. B. D. Doeblin, 'Measurement systems -Application and Design, McGraw Hill New York.
2. John P. Bentley, 'Principles of Measurement System', Pearson Education.
3. J. W. Dally, W. F. Reley and K. G. McConnel, 'Instrumentation for Engineering measurements 2/e, John Wiley & sons Inc, New York, 1993.
4. Curtis D. Johnson, 'Process Control Instrumentation Technology', Prentice Hall of India Private Limited, New Delhi.
5. Dale E. Soberg, Thomson F Edgar, 'Process Dynamics and Control', 2/e, Wiley.
6. K. B. Klaasen, 'Electronic Measurement. And Instrumentation', Cambridge University Press.
7. WaltenegusDargie& Christian Poella Bauer, "Fundamentals of Wireless Sensor networks": Wiley Series.
8. Jun Zheng& Abbas Jamalipour, Wireless sensor Networks, A Networking perspective, Wiley.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Generalized performance characteristics of instruments - Static characteristics, static calibration, memory, precision and bias, dynamic characteristics, development of mathematical model of various measurement systems. Classification of instruments based on their order.	6	15
II	General concept of transfer function (with special reference to measuring systems) Dynamic response and frequency response studies of zero order, first order and second order instruments. Response of a general form of instrument to a periodic input. Response of a general form of instrument to a transient input. Requirement of instrument transfer function to ensure accurate measurement.	9	15
FIRST INTERNAL EXAM			
III	Plant level automation- process and instrumentation diagrams- Performance modeling — role of performance modeling- performance measures.	9	15
IV	Petrinet models- introduction to petrinets - basic definitions and analytical techniques, Smart Sensors, Wireless sensors and Wireless Sensor network protocol	6	15
SECOND INTERNAL EXAM			
V	Virtual instrumentation – Definition, flexibility – Block diagram and architecture of virtual instruments – Virtual instruments versus traditional instruments	6	20
VI	Review of software in virtual instrumentation - VI programming techniques, sub VI, loops and charts, arrays, clusters and graphs, case and sequence structures, formula nodes, string and file input / output	6	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7115	System Identification & Parameter Estimation	3-0-0	3	2015

Course Objectives

1. To design suitable performance measure to meet the specification requirements.
2. To analyse the physical system and design the structure of system model by optimizing the suitable performance criteria by satisfying the constraints over the system parameter.
3. To apply the design algorithms to various physical systems with unknown system parameters.
4. Provides a solid foundation on modelling and analysis of system with stochastic parameter.

Syllabus

Principles of Modelling and Transfer function identification; Properties of estimates; validation of models; impulse Response. Step Response; Frequency response; State Space Models; Distributed parameter models; model structures; multivariable systems; Transfer function from frequency response. Fourier Analysis and Spectral analysis; Correlation Identification; Parameter Estimation Methods; Guiding principles behind parameter estimation methods; Minimizing prediction errors; Instrumental variable method; consistency and identifiability; Recursive methods RLS Algorithm, Recursive IV Method; Recursive Prediction Error Method, recursive pseudo-linear regressions; Experiment Design and Choice of Identification Criterion; Optimal Input design; Persistently exciting condition; Optimal input design for higher order black box models; Choice of sampling interval and pre-sampling filters; Choices of Identification criterion; Choice of norm; variance; optimal instruments.

Expected Outcome

Upon successful completion of this course, students will be able to:
1. Identify suitable estimation algorithm for implementation.
2. Formulate and design suitable structure of system model.
3. Apply iterative estimation algorithms to model various physical systems.
4. Implement optimal control algorithms to track the response of the system with unknown system parameters.

References

1. LennartLjung, System Identification Theory for the User, Prentice Hall Information Systems Science Series, 1987.

2. Sinha N. K., Kuztsas, 'System Identification and Modeling of Systems', 1983.
3. Harold W. Sorensen, 'Parameter Estimation', Marcel Dekker Inc, New York, 1980.
4. Daniel Graupe, Identification of Systems,VanNostrand.
5. Tohru Katayama, '*Subspace Methods for System Identification*', Springer-Verlag London Limited, 2005.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Principles of Modelling and Transfer function identification: System Identification and Stochastic Modeling- Structure and parameter estimation. Properties of estimates – validation of models-impulse Response. Step Response - Frequency response- transfer function from these - disturbances and transfer function.	6	15
II	State Space Models: Distributed parameter models- model structures, identifiability of model structures - signal spectra - single realization and ergodicity - multivariable systems - Transfer function from frequency response. Fourier Analysis and Spectral analysis -Estimating Disturbance Spectrum - Correlation Identification - Practical Implementation - Pseudo random binary signals - maximum length sequences - generation using hardware - random number generation on digital computer.	9	15
FIRST INTERNAL EXAM			
III	Parameter Estimation Methods: Guiding principles behind parameter estimation methods. Minimizing prediction errors. Linear regression and least squares methods. Statistical framework for parameter estimation. Maximum likelihood estimation. Correlating prediction errors with past data.	9	15
IV	Instrumental variable method, consistency and identifiability, Recursive methods .RLS Algorithm, Recursive IV Method- Recursive Prediction Error Method, recursive pseudo-linear regressions. Choice of updating step.	6	15
SECOND INTERNAL EXAM			
V	Experiment Design and Choice of Identification Criterion: Optimal Input design. Persistently exciting condition. Optimal input design for higher order black box models.	6	20
VI	Choice of sampling interval and pre-sampling filters. Choices of Identification criterion. Choice of norm, variance, optimal instruments.	6	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7313	Dynamics of Power Converters	3-0-0	3	2015

Course Objectives

To equip the students with the dynamic aspect of different converters and their analysis

Syllabus

Fundamentals of Steady state converter modelling and analysis-Steady-state equivalent circuits-losses and efficiency- Inclusion of semiconductor conduction losses in converter model-Small-signal AC modelling- Averaging of inductor/capacitor waveforms- perturbation and linearization-State-Space Averaging-Circuit Averaging and averaged switch modelling- Canonical Circuit Model- Manipulation of dc-dc converters' circuit model into Canonical Form-Modelling the pulse width modulator-Converter Transfer Functions:-Review of frequency response analysis techniques -Converter transfer functions-graphical construction. Measurement of ac transfer functions and impedances-Controller Design-Effect of negative feedback on the network transfer functions-loop transfer function-Controller design specifications- applications to the basic dc-dc topologies - Practical methods to measure loop gains-Converters in Discontinuous Conduction Mode-AC and DC equivalent circuit modelling of the discontinuous conduction mode-Generalised Switch Averaging-small-signal ac modelling of the dcm switch network- Current-Mode Control-Average Current-mode Control-Peak Current-mode control-first order models accurate models for current-mode control-application to basic dc-dc converter topologies-Subharmonic oscillation for d> 0.5; Slope compensation- Discontinuous conduction mode in current-mode control.

Course Outcome:

Upon successful completion of this course, students will be able to:

1. Develop dynamic models of switched power converters using state space averaging and circuitaveraging techniques.
2. Develop converter transfer functions.
3. Design closed loop controllers for DC-DC power converters.
4. Design and implement current mode control for DC-DC converters.

REFERENCES:

1. Robert Erickson and DraganMaksimovic, '*Fundamentals of Power Electronics*', SpringerIndia
2. John G. Kassakian*, et al., 'Principles of Power Electronics', Pearson Education*

COURSE PLAN

Module	Course description	Hours	End semester exam % marks
1	Fundamentals of Steady state converter modelling and analysis, Steady-state equivalent circuits, lossesand efficiency. Inclusion of semiconductor conduction losses in converter model.	6	15%

2	Small-signal AC modelling- Averaging of inductor/capacitor waveforms- perturbation andlinearisation.State-Space Averaging-Circuit Averaging and averaged switch modelling-Canonical Circuit Model-Manipulation of dc-dc converters' circuit model into Canonical Form-Modelling the pulse widthmodulator	9	20%
	First Internal Exam		
3	Converter Transfer Functions:-Review of frequency response analysis techniques- Bode plots –Converter transfer functions-graphical construction. Measurement of ac transfer functions andimpedances.	6	15%
4	Controller Design: Effect of negative feedback on the network transfer functions-loop transferfunction-Controller design specifications- PD, PI and PID compensators - applications to the basic dc-dctopologies - Practical methods to measure loop gains: Voltage and current injection.	6	15%
	Second Internal Exam		
5	Converters in Discontinuous Conduction Mode: AC and DC equivalent circuit modelling of thediscontinuous conduction mode-Generalised Switch Averaging-small-signal ac modelling of the dcmswitch network-	6	15%
6	Current-Mode Control: Average Current-mode Control, Peak Current-mode control-first order modelsaccuratemodels for current-mode control-application to basic dc-dc converter topologies-Sub-harmonic oscillation for d> 0.5; Slope compensation- Discontinuous conduction mode in current mode control.	9	20%
	End Semester Exam		

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7117	Estimation Theory	**3-0-0**	**3**	**2015**

Course Objectives

To train the students to implement state feedback controller by estimating the state of the system.

1. Able to apply the estimation algorithms to estimate unknown quantities from the available measured signals.
2. Provides a solid foundation on Matrix algebra, Probability and Statistics

Course Content:

Elements of Probability and Random Process, Continuous Probability, Expectation, Variance, Covariance, Random Variables, Expectation, Covariance, Least Square Estimation, Wiener filtering, Kalman Filter, Sequential Kalman Filtering, Continuous Time Kalman Filter, Steady State Filter, Optimal Smoothing.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Select suitable estimation for implementation.
2. Apply estimation algorithms to estimate signals and parameters of the system.
3. Implement optimal estimation algorithms to estimate signals from noisy data for linear as well as nonlinear systems.

References

1. Dan Simon, “Optimal State Estimation Kalman, H infinity and Nonlinear Approaches,” Wiley Inter-science, John Wiley & Sons, Inc., Publication, 2006.
2. Athanasios Papoulis and S. UnnikrishnaPillai, “Probability, Random Variables and Stochastic Process,” Tata McGraw-Hill Publishing Company Limited, New Delhi, India, 2002.
3. Sheldon M. Ross, “Introduction to Probability and Statistics for Engineers and Scientists,” 3/e, Academic Press, Delhi, India, 2005.
4. Jerry M. Mendel, “Lessons in Estimation Theory for Signal Processing, Communications and Control,” Prentice Hall PTR, Englewood Cliffs, New Jersey, USA, 1995.
5. Paul Zarchan and Howard Musof, “Fundamentals of Kalman Filtering: A Practical Approach,” AIAA Inc. Alexander Bell Drive, Reston, Vergenia, 2000.
6. Robert Grover Brown and Patrick Y. C. Hwang, “Introduction to Random Signals and Applied Kalman Filtering,” 3/e, John Wiley & Sons, Inc., Publication, Canada, 1997.
7. Alexander D. Poularikas and Zayed M. Ramadan, “Adaptive Filtering Primer with MATLAB,” CRC Press, Taylor & Francis, Boca Raton, London, 2006.

COURSE PLAN			
Module	**Contents**	**Hours Allotted**	**% of Marks in End-Semester Examination**
I	Elements of Probability and Random Process: Sample Spaces and Events - Axioms of Probability - Conditional Probability - Continuous Probability - Probability Functions - Bayes' Formula- Random Variables.	6	15
II	Expectation - Variance - Covariance - White and Colored Noises-Correlated Noise. Least Square Estimation: Estimation of Constant. Weighted Least Square Estimation, Recursive Least Square Estimation.	9	15
FIRST INTERNAL EXAM			
III	Wiener filtering - Propagation of States and Co-Variance - Continuous Time and Discrete Time Systems. Kalman Filter: Discrete-time Kalman Filter- Properties- Propagation of Covariance.	6	15
IV	Sequential Kalman Filtering - Information Filtering – Square root Filtering - Correlated Process and Measurement Noise - Colored Process and Measurement Noise- Steady State Filtering.	9	15
SECOND INTERNAL EXAM			
V	Continuous Time Kalman Filter: Discrete time and Continuous time White Noise – Solution through Riccati Equation – Generalization of Continuous -time Filter – Steady State Filter.	6	20
VI	Optimal Smoothing: Fixed-point Smoothing- Fixed-lag Smoothing – Fixed-interval Smoothing. Nonlinear Kalman Filter: Linearized Kalman Filter – Extended Kalman Filter – Higher Order Approaches – Parameter Estimation.	6	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7119	Multivariable Control Theory	3-0-0	3	2015

Course Objectives

1. To analyse and synthesise linear multivariable robust control systems.
2. To design multivariable controllers for robust performance.

Course Content:

Introduction to multivariable control, Transfer function matrices for Multi Input Multi Output (MIMO) systems;Representations of MIMO systems, MIMO Nyquist stability criterion, multivariable poles and zeros, pole polynomial, zero polynomial,Introduction to MIMO robustness; Limitations on performance in MIMO systems; MIMO Input-output controllability; General control configuration with uncertainty for MIMO systems; Definitions of robust stability and robust performance for MIMO systems; Robust stability with structured and unstructured uncertainty for MIMO systems; Robustness analysis including the structured singular value; Multivariable stability margin and the structured singular value μ, the performance robustness theorem; Uniform MIMO System Circulant and Anti-circulant MIMO System.

Expected Outcome

Upon successful completion of this course, students will be able to:

1. Analyse and synthesise linear multivariable robust control systems
2. Design multivariable controllers

References

1. Multivariable Feedback Control - Analysis and Design, 2nd ed; SigurdSkogestad and Ian Postlethwaite Wiley, 2005
2. T. Glad and L. Ljung, Control Theory: Multivariable & Nonlinear Methods, Taylor & Francis, 2000.
3. C-T Chen, Linear System Theory and Design, 3rd edition; Oxford University Press, 1998;

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination
I	Introduction to multivariable control, Transfer function matrices for Multi Input Multi Output (MIMO) systems; Representations of MIMO systems, MIMO Nyquist stability criterion, multivariable poles and zeros, pole polynomial, zero polynomial, Singular value decomposition of transfer matrices.	6	15

II	Introduction to MIMO robustness; Limitations on performance in MIMO systems; MIMO Input-output controllability; General control configuration with uncertainty for MIMO systems.	9	15
FIRST INTERNAL EXAM			
III	Definitions of robust stability and robust performance for MIMO systems; Robust stability with different structured and unstructured uncertainty for MIMO systems.	9	15
IV	Robustness analysis including the structured singular value; Multivariable stability margin and the structured singular value μ, the performance robustness theorem.	6	15
SECOND INTERNAL EXAM			
V	Uniform MIMO Systems - Stability Analysis of Uniform MIMO Systems. Circulant and Anti-circulant MIMO System. Characteristic transfer functions of Uniform MIMO System and Anti-circulant Systems. Oscillation Index of Uniform MIMO systems.	6	20
VI	Relative Gain Array and properties, Decoupling controllers, Decentralised controllers	6	20
END SEMESTER EXAM			

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7121	Biomedical Instrumentation	**3-0-0**	**3**	**2015**

Course Objectives

To provide an introduction to the modern Biomedical instruments and systems, features and applications.

Syllabus

Introduction to the physiology of cardiac, nervous; muscular and respiratory systems; Action potentials -De-polarization; repolarization; Absolute and relative refractory periods; Generation propagation and transmission; Measurement of electrical activities in heart, Electrocardiography; Measurement of electrical activities in brain, Electroencephalogram; Measurement of electrical activities in muscles; Determination of conduction velocity in a nerve fiber. Important applications of EMG; Measurement of blood flow; Direct and Indirect methods; Therapeutic Equipment - Cardiac pace-makers, Types of pace-makers; Defibrillators, Types of defibrillators, Electrodes used in defibrillators, diathermy machines, Micro wave and short wave diathermy machines. Introduction to Biomedical signal processing; Analysis of x-rays; CT and MRI images; Basic methods; Instrumentation for clinical laboratory; Measurement of pH value of blood, ESR measurements, GSR measurement, modern imaging modalities ; X-ray machines, Diagnostic X-rays- Computed Tomography; Ultra sonography; Magnetic resonance imaging. Nuclear medicine; Radio isotopic instrumentation; Medical uses of isotopes; Applications of robotics in medical field; Cyber knife.

Expected Outcome

Upon successful completion of this course, students will have insight into operation and maintenance of modern biomedical equipments used in clinical practice.

References

1. R. S. Khandpur, *Handbook of Biomedical Instrumentation*, TMH Publishing Company Ltd., New Delhi.
2. Joseph J. Carr, John M Brown, *Introduction to Biomedical Equipment Technology*, Pearson Education (Singapore) Pvt. Ltd.
3. Leslie Cromwell, "*Biomedical Instrumentation and Measurements*", Prentice Hall India, New Delhi.

COURSE PLAN

Module	Contents	Hours Allotted	% of Marks in End-Semester Examination

I	Introduction to the physiology of cardiac, nervous, muscular and respiratory systems. Transducers and Electrodes, Action potentials- De-polarization – repolarization- Absolute and relative refractory periods- generation propagation and transmission. Significance of after potentials, Different types of transducers and their selection for biomedical applications.	6	15
II	Electrodes used in Biomedical engineering. Electrodes for ECG, EEG, EMG, etc. Biomaterials-Metals, Ceramics, Polymeric materials and their applications.	6	15
FIRST INTERNAL EXAM			
III	Measurement of electrical activities in heart, brain and muscles - Electrocardiography- EEG machine, Disease diagnosis from ECG, Computer aided electro cardiographs- Applications of ECG. Electroencephalogram and their interpretation. EEG machine applications, Rapid eye movement- Electromyography, EMG machines, Conduction velocity in a nerve fiber. Important applications of EMG.	9	15
IV	Electromagnetic and ultrasonic measurement of blood flow, various methods, Therapeutic Equipment - Cardiac pace-makers, Types of pace-makers, Defibrillators, Types of defibrillators, Electrodes used in defibrillators, diathermy machines, Microwave and short wave diathermy machines.	9	15
SECOND INTERNAL EXAM			
V	Introduction to Biomedical signal processing, Methods of signal processing – Digital and analogue. Introduction to Biomedical image processing- Analysis of x-rays, CT and MRI images – Basic methods.	6	20
VI	Instrumentation for clinical laboratory - Measurement of pH value of blood, ESR, and GSR measurement, modern imaging modalities - X-ray machines, Diagnostic x-rays - Computed Tomography – Ultrasonography - Magnetic resonance imaging - Nuclear medicine - Radio isotopic instrumentation - Medical uses of isotopes – Applications of robotics in medical field- Cyber knife.	6	20
END SEMESTER EXAM			

Course No.	**Course Name**	**L-T-P**	**Credits**	**Year of Introduction**
01EE7315	Hybrid Electric Vehicles	3-0-0	3	2015

Course Objectives:

To present a comprehensive overview of Electric and Hybrid Electric Vehicle

Syllabus

Introduction to Hybrid Electric Vehicles, Conventional Vehicles, Hybrid Electric Drive-trains, Electric Propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, switched reluctance motor, Energy Storage Requirements in Hybrid and Electric Vehicles, Sizing the drive system, Design of a Hybrid Electric Vehicle , Energy Management Strategies.

Expected Outcome:

Upon successful completion of this course, students will be able to

1. Choose a suitable drive scheme for developing an electric hybrid vehicle depending on resources
2. Design and develop basic schemes of electric vehicles and hybrid electric vehicles.
3. Choose proper energy storage systems for vehicle applications
4. Identify various communication protocols and technologies used in vehicle networks.

References

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003

2 MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

3 James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

COURSE PLAN

Module	**Course description**	**Hours**	**End semester exam % marks**
1	Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission	7	15%

	characteristics, mathematical models to describe vehicle performance.		
2	Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.	8	15%
	First Internal Exam		
3	Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency	8	15%
4	Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices.	7	15%
	Second Internal Exam		
5	Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV).	6	20%
6	Communications, supporting subsystems: In vehicle networks- CAN, Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies.	6	20%
	End Semester Exam		

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7191	Seminar II	0-0-2	2	2015

Course Objectives

To make students

1. Identify the current topics in the specific stream.
2. Collect the recent publications related to the identified topics.
3. Do a detailed study of a selected topic based on current journals, published papers and books.
4. Present a seminar on the selected topic on which a detailed study has been done.
5. Improve the writing and presentation skills.

Approach

Students shall make a presentation for 20-25 minutes based on the detailed study of the topic and submit a report based on the study.

Expected Outcome

Upon successful completion of the seminar, the student should be able to

1. Get good exposure in the current topics in the specific stream.
2. Improve the writing and presentation skills.
3. Explore domains of interest so as to pursue the course project.

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7193	Project (Phase 1)	0-0-12	6	2015

Course Objectives

To make students

1. Do an original and independent study on the area of specialization.
2. Explore in depth a subject of his/her own choice.
3. Start the preliminary background studies towards the project by conducting literature survey in the relevant field.
4. Broadly identify the area of the project work, familiarize with the tools required for the design and analysis of the project.
5. Plan the experimental platform, if any, required for project work.

Approach

The student has to present two seminars and submit an interim Project report. The first seminar would highlight the topic, objectives, methodology and expected results. The first seminar shall be conducted in the first half of this semester. The second seminar is the presentation of the interim project report of the work completed and scope of the work which has to be accomplished in the fourth semester.

Expected Outcome

Upon successful completion of the project phase 1, the student should be able to

1. Identify the topic, objectives and methodology to carry out the project.
2. Finalize the project plan for their course project.

SEMESTER – IV

Syllabus and Course Plan

Course No.	Course Name	L-T-P	Credits	Year of Introduction
01EE7194	Project (Phase 2)	0-0-23	12	2015

Course Objectives

To continue and complete the project work identified in project phase 1.

Approach

There shall be two seminars (a mid term evaluation on the progress of the work and pre submission seminar to assess the quality and quantum of the work). At least one technical paper has to be prepared for possible publication in journals / conferences based on their project work.

Expected Outcome

Upon successful completion of the project phase II, the student should be able to

1. Get a good exposure to a domain of interest.
2. Get a good domain and experience to pursue future research activities.