CURRICULUM AND SYLLABI

M.Tech.

in

INDUSTRIAL POWER AND AUTOMATION

(With effect from Academic Year 2018-2019)

DEPARTMENT OF ELECTRICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
CALICUT - 673601

Vision of the Department of Electrical Engineering

To be nationally and internationally recognized in providing electrical engineering education and training candidates to become well-qualified engineers who are capable of making valuable contributions to their profession and carrying out higher studies successfully.

Mission of the Department in pursuance of its vision

To offer high quality programs in the field of electrical engineering, to train students to be successful both in professional career as well as higher studies and to promote excellence in teaching, research, collaborative activities and contributions to the society.

The Program Educational Objectives (PEOs) of
M. Tech. in INDUSTRIAL POWER AND AUTOMATION

PEO1	To prepare post graduate students to excel in technical profession, industry and/or higher education by providing a strong foundation.
PEO2	To transform engineering students to expert engineers and managers so that they could comprehend, analyse, design and create novel products and solutions to Engineering problems that are technically sound, economically feasible and socially acceptable.
PEO3	To train students to exhibit professionalism, keep up ethics in their profession and relate engineering issues to a broader social context.
PEO4	To develop communication skills and team work and to nurture multidisciplinary approach in problem solving.

The Program Outcomes (POs) of

M. Tech. in INDUSTRIAL POWER AND AUTOMATION

PO1	An ability to independently carry out research/ investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4	Acquire technical competence, comprehensive knowledge and understanding of industrial process and automation.
PO5	Inculcate the role of research in developing and maintaining knowledge of the state-of-the-art in various technologies in industries. Acquire the skill to design, develop and modify systems in hardware and software platforms to meet desired needs within realistic constraints.

CURRICULUM

This program is offered in four semesters. The total minimum credit for completing the M.Tech program in Industrial power and automation is 60. The structure of the programme shall be the following:

Semester 1

Sl.No	Code	Title	L	T	P/S	C
1	MA6003D	Mathematical Methods for Power Engineering	3	0	-	3
2	EE6401D	Energy Auditing & Management	3	0	-	3
3	EE6403D	Computer Controlled Systems	3	0	-	3
4	EE6405D	Artificial Intelligence & Automation	3	0	-	3
5		Elective –1	3	0	-	3
6	EE6491D	Industrial Power & Automation Laboratory1	-	-	2	1
7	EE6493D	Seminar	-	-	2	1
	Total Credits		15	0	4	17

Semester 2

Sl.No	Code	Title	L	T	P/S	C
1	EE6402D	Process control and Automation	3	0	-	3
2	EE6406D	Industrial Drives & Control	3	0	-	3
3	EE6404D	Industrial Instrumentation	3	0	-	3
4		Elective –2	3	0	-	3
5		Elective – 3	3	0	-	3
6	EE6494D	Mini Project	-	-	3	2
7	EE6492D	Industrial Power & Automation Laboratory 2	-	-	2	1
	Total Credits		15	0	4	18

Semester 3

S.No	Code	Title	L	T	P/S	C
1	EE7491D	Project Part– 1	0	0	30	10
2	EE7493D	Industrial Training/Internship				1
	Total credits		0	0	30	11

Note: - EE7493D Training/Internship in reputed Industries /Higher learning Institutes shall be completed during summer vacation and will be credited in 3rd semester.

Semester 4

S.No	Code	Title	L	T	P/S	C
1	EE7492D	Project Part – 2	0	0	30	14
	Total credits		0	0	30	14

LIST OF ELECTIVES

S.NO	CODE	TITLE	CREDIT
1.	EE6421D	Smart Grid Technologies and Applications	3
2.	EE6422D	Engineering Optimization and Algorithms	3
3.	EE6423D	Industrial Communication	3
4.	EE6424D	Robotic Systems and Applications	3
5.	EE6425D	Sustainable Energy Systems & Design	3
6.	EE6426D	Distribution Systems Management and Automation	3
7.	EE6428D	SCADA Systems & Applications	3
8.	EE6429D	Wireless & Sensor Networks	3
9.	EE6430D	Network & Data Security	3
10.	EE6432D	Advanced Algorithms & Data Structure Analysis	3
11.	EE6434D	Internet of Things and Applications	3
12.	EE6436D	Industrial Load Modelling & Control	3

13.	EE6101D	Systems Theory	3
14.	EE6102D	Optimal and Robust Control	3
15.	EE6103D	Measurements and Instrumentation	3
16.	EE6104D	Advanced Instrumentation	3
17.	EE6105D	Digital Control: Theory & Design	3
18.	EE6106D	Stochastic Modeling and Identification of Dynamical System	3
19.	EE6108D	Non Linear Systems and Control	3
20.	EE6121D	Data Acquisition and Signal Conditioning	3
21.	EE6122D	Biomedical Instrumentation	3
22.	EE6125D	Adaptive Control Theory	3
23.	EE6134D	Networked Control and Multiagent Systems	3
24.	EE6136D	Guidance, Navigation and Control	3
25.	EE6140D	Advanced Soft Computing Techniques	3
26.	EE6201D	Computer Methods in Power System Analysis	3
27.	EE6204D	FACTS and Custom Power	3
28.	EE6206D	Digital Protection of Power Systems	3
29.	EE6203D	Distributed Generation & micro grid	3
30.	EE6222D	Wide Area Monitoring & Control of Power Systems	3
31.	EE6221D	Power Quality Issues and Remedial Measures	3
32.	EE6301D	Power Electronic Circuits	3
33.	EE6303D	Dynamics of Electrical Machines	3
34.	EE6321D	Power Semiconductor Devices and Modelling	3
35.	EE6322D	Static VAR Controllers and Harmonic Filtering	3
36.	EE6325D	Linear and Digital Electronics	3
37.	EE6327D	Implementation of DSP Algorithms	3
38.	EE6329D	Advanced Microprocessor Based Systems	3
39.	EE6226D	Hybrid and Electric Vehicles	3
40.	EE6304D	Modern Digital Signal Processors	3
41.	EE6523D	Condition Monitoring of Power Equipment	3
42.	EE6202D	Power System Dynamics and Control	3
43.	EC6421D	Digital Image Processing techniques	3
44.	EC6434D	Linear & Nonlinear Optimization	3
45.	EC6431D	Pattern Recognition and Analysis	3
46.	MA6010D	Simulation and Modelling	3
47.	MA7165D	Statistical Digital Signal Processing	3

48.	MA7166D	Statistical Methods For Quality Management	3
49.	MA7355D	Fuzzy Set Theory and Applications	3
50.	MA8154D	Wavelets Theory	3
51.	MA8163D	Advanced Operations Research	3
52.	MA6011D	Design of Experiments	3
53.	ME6313D	Industrial Automation & Robotics	3
54.	MS9001D	Research Methodology	4
55.	CS6125D	Computer Networking	4
56.	CS6141D	Distributed Computing	4
57.	CS6191D	Mathematical Foundations of Machine Learning	4
58.	CS6285D	Information Security Management	4
59.	ME6612D	Finite Element Methods and Applications	3
60.	ME6636D	Computer Graphics	3
61.	ME6626D	Product Design	3
62.	ME6324D	Industrial Machine Vision	3
63.	ME6322D	Six Sigma	3
64.	ME6321D	Mechatronics Systems	3
65.	ME6147D	Technical Entrepreneurship	3
66.	ME6148D	Management of Technology and Innovation	3
67.	MS6117D	Business Research Methods	3

Notes:
(1) A minimum of **60** credits have to be earned for the award of M. Tech Degree in this Programme.
(2) Communicative English and Audit courses are optional.
(3) List of Electives offered in each semester will be announced by the Dept.
(4) Any other course of NITC approved by senate offered in the Institute can also be credited as electives with the prior approval from the Programme Coordinator.

MA6003D MATHEMATICAL METHODS FOR POWER ENGINEERING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Apply notions of vector spaces and linear transformations in engineering problems
CO2. Diagonalise linear operators and quadratic forms.
CO3: Handle various linear programming problems and apply the simplex method for solving linear programming problems in various fields of science and technology.
CO4: Solve constrained and unconstrained nonlinear programming problems.
CO5: Apply the concept of random variables, functions of random variable and their probability distribution in problems involving uncertainty.
CO5: Classify stochastic processes using autocorrelation function.

Module 1: **Linear Algebra (10 hours)**

Vector spaces, subspaces, Linear dependence, Basis and Dimension, Linear transformations, Kernels and Images , Matrix representation of linear transformation, Change of basis, Eigen values and Eigen vectors of linear operator

Module 2: Optimisation Methods I (10 hours)

Mathematical formulation of Linear Programming Problems, Simplex Method, Duality in Linear Programming, Dual Simplex method.

Module 3: Optimisation Methods II (10 hours)

Non Linear Programming preliminaries, Unconstrained Problems, Search methods, Fibonacci Search, Golden Section Search, Constrained Problems, Lagrange method, Kuhn-Tucker conditions

Module 4: Operations on Random Variables (9 hours)

Random Variables, Distributions and Density functions, Moments and Moment generating function, Independent Random Variables, Marginal and Conditional distributions, Conditional Expectation, Elements of stochastic processes, Classification of general stochastic processes.

Text Books and References:

1. Kenneth Hoffman and Ray Kunze,' *Linear Algebra'*, 2nd Edition, PHI, 1992.
2. Erwin Kreyszig, '*Introductory Functional Analysis with Applications'*, John Wiley & Sons, 2004.
3. Irwin Miller and Marylees Miller, '*John E. Freund's Mathematical Statistics'*, 6th Edn, PHI, 2002.
4. J. Medhi, '*Stochastic Processes'*, New Age International, New Delhi., 1994
5. A Papoulis, '*Probability, Random Variables and Stochastic Processes'*, 3rd Edition, McGraw Hill, 2002
6. John B Thomas, *'An Introduction to Applied Probability and Random Processes'*, John Wiley, 2000
7. Hillier F S and Liebermann G J, '*Introduction to Operations Research'*, 7th Edition, McGraw Hill, 2001
8. Simmons D M, '*Non Linear Programming for Operations Research'*, PHI, 1975

EE6401D ENERGY AUDITING & MANAGEMENT

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Recognize the role of energy managers and use the skills and techniques required to implement energy management.

CO2: Identify and quantify the energy intensive business activities in an organization.

CO3: Describe the standard methodologies for measuring energy in the workplace and energy audit Instruments

CO4: Analyze energy efficient control scheme for electric motors and perform case study on load matching and selection of motors.

CO5: Explain the energy conservation methods in motors, pumps, fans, compressors, transformers, geysers, lighting schemes, air conditioning, refrigeration, cool storage.

CO6: Conduct a walkthrough audit in various industries.

Module 1: (9 hours)

System approach and End use approach to efficient use of Electricity; Electricity tariff types; Energy auditing: Types and objectives-audit instruments- ECO assessment and Economic methods-specific energy analysis-Minimum energy paths-consumption models-Case study.

Module 2: (10 hours)

Electric motors-Energy efficient controls and starting efficiency-Motor Efficiency and Load Analysis- Energy efficient /high efficient Motors-Case study; Load Matching and selection of motors.

Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing -Optimal operation and Storage; Case study

Module 3: (10 hours)

Transformer Loading/Efficiency analysis, Feeder/cable loss evaluation, case study.

Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses-Location-Placement-Maintenance, case study.

Peak Demand controls- Methodologies-Types of Industrial loads-Optimal Load scheduling-case study.

Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic ballast-Power quality issues-Luminaries, case study.

Module 4: (10 hours)

Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study;

Electric loads of Air conditioning & Refrigeration-Energy conservation measures- Cool storage. Types-Optimal operation-case study; Electric water heating-Gysers-Solar Water Heaters- Power Consumption in Compressors, Energy conservation measures; Electrolytic Process; Computer Controls- software-EMS

References

1. Y P Abbi and Shashank Jain, *Handbook on Energy Audit and Environment Management* , TERI, 2006
2. Albert Thumann, William J. Younger, Terry Niehus , *Handbook of Energy Audits*, 2009

3. Giovanni Petrecca, *Industrial Energy Management: Principles and Applications*, The Kluwer international series -207,1999
4. Anthony J. Pansini, Kenneth D. Smalling, *Guide to Electric Load Management*, Pennwell Pub; (1998)
5. Howard E. Jordan, Energy-*Efficient Electric Motors and Their Applications*, Plenum Pub Corp; 2nd edition (1994)
6. Turner, Wayne C, *Energy Management Handbook*, Lilburn, The Fairmont Press, 2001
7. Albert Thumann, *Handbook of Energy Audits*, Fairmont Pr; 5th edition (1998)
8. IEEE Bronze Book, *Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities*, IEEE Inc, USA. 2008
9. Albert Thumann, P.W, *Plant Engineers and Managers Guide to Energy Conservation,* Seventh Edition,TWI Press Inc, Terre Haute, 2007
10. Donald R. W., *Energy Efficiency Manual,* Energy Institute Press, 1986
11. Partab H., *Art and Science of Utilisation of Electrical Energy*, Dhanpat Rai and Sons, New Delhi. 1975
12. Tripathy S.C, *Electric Energy Utilization And Conservation*, Tata McGraw Hill, 1991
13. NESCAP Guide Book on Promotion of Sustainable Energy Consumption, 2004
14. IEEE Bronze Book, IEEE STD 739
15. IEEE Recommended Practices for Energy Management in Industrial and Commercial Facilities
16. Barney L. Capehart, Wayne C. Turner , William J. Kennedy, Guide *to Energy Management*, Fairmont Press, 6th edition ,April 23, 2008.
17. Donald R. Wulfinghoff*, Energy Efficiency Manual: for everyone who uses energy, pays for utilities, designs and builds, is interested in energy conservation and the environment*, Energy Institute Press March 2000.
18. Albert Thumann., William J. Younger, *Handbook of Energy Audits*,Fairmont Press, 7th Edition, November 12, 2007.
19. Certified Energy Manager Exam Secrets Study Guide: CEM Test Review for the Certified Energy Manager Exam CEM Exam Secrets Test Prep Team Mometrix Media LLC (2009)
20. Albert Thuman, D. Paul Mehta , *Handbook of Energy Engineering*, Fairmont Press, 6th edition , June 24, 2008.

EE6403D COMPUTER CONTROLLED SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Identify the scientific and mathematical principles and methodologies relevant to computer control of systems.
CO2: Describe the fundamentals of PLC and its architecture.
CO3: Explain the PLC programming fundamentals, process logic and human machine interface.
CO4: Describe DCS architecture and configuration.
CO5: Analyze in detail the case studies of PLC, SCADA and DCS.
CO6: Perform inter task communication, synchronization and real time memory management.

Module 1: Multivariable Control (11 hours)

Multivariable control- Basic expressions for MIMO systems- Singular values- Stability norms- Calculation of system norms- Robustness- Robust stability- H2 / H∞ Theory- Solution for design using H2 / H∞ - Case studies. Interaction and decoupling- Relative gain analysis- Effects of interaction- Response to disturbances- Decoupling- Introduction to batch process control.

Module 2: Programmable Logic Controllers (9 hours)

Programmable logic controllers- Organisation- Hardware details- I/O- Power supply- CPU- Standards- Programming aspects- Ladder programming- Sequential function charts- Man- machine interface- Detailed study of one model- Case studies.

Module 3: Large Scale Control System (11 hours)

SCADA: Introduction, SCADA Architecture, Different Communication Protocols, Common System Components, Supervision and Control, HMI, RTU and Supervisory Stations, Trends in SCADA, Security Issues

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

Module 4: Real Time Systems (8 hours)

Real time systems- Real time specifications and design techniques- Real time kernels- Inter task communication and synchronization- Real time memory management- Supervisory control- direct digital control- Distributed control- PC based automation.

References

1. Shinskey F.G., *Process control systems: application, Design and Tuning*, McGraw Hill International Edition ,Singapore,1988.
2. Be.langer P.R., Control *Engineering: A Modern Approach*, Saunders College Publishing , USA, 1995.
3. Dorf, R.C. and Bishop R. T , *Modern Control Systems* , Addison Wesley Longman Inc., 1999
4. Laplante P.A., *Real Time Systems: An Engineers Handbook*, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.

5. Constantin H. Houpis and Gary B. Lamont, *Digital Control systems*, McGraw Hill Book Company, Singapore, 1985.
6. Stuart A. Boyer: SCADA-*Supervisory Control and Data Acquisition*, Instrument Society of America Publications, USA, 1999
7. Gordon Clarke, Deon Reynders , Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems, Newnes Publications, Oxford, UK,2004
8. Efim Rosenwasser, Bernhard P. Lampe, *Multivariable computer-controlled systems: a transfer function approach*, Springer, 2006

EE6405D ARTIFICIAL INTELLIGENCE & AUTOMATION

Pre-requisite: Basics of neural networks

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Identify potential areas for automation and justify need for automation
CO2: Select suitable major control components required to automate a process or an activity
CO3: Identify suitable automation hardware for the given application
CO4: Explain Artificial" Intelligence and Identify systems with Artificial Intelligence.
CO5: Implement classical Artificial Intelligence techniques, such as search algorithms, minimax algorithm, neural networks, tracking, robot localization.

Module 1 (10 hours)

Introduction: Overview and Historical Perspective, Turing test, Physical Symbol Systems and the scope of Symbolic AI, Agents. State Space Search: Depth First Search, Breadth First Search, DFID. Heuristic Search: Best First Search, Hill Climbing, Beam Search, Tabu Search. Randomized Search: Simulated Annealing, Genetic Algorithms, Ant Colony Optimization. Finding Optimal Paths: Branch and Bound, A*, IDA*, Divide and Conquer approaches, Beam Stack Search.

Module 2 (9 hours)

Problem Decomposition: Goal Trees, AO*, Rule Based Systems, Rete Net. Game Playing: Minimax Algorithm, AlphaBeta Algorithm, SSS*. Planning and Constraint Satisfaction: Domains, Forward and Backward Search, Goal Stack Planning, Plan Space Planning, Graphplan, Constraint Propagation. Logic and Inferences: Propositional Logic, First Order Logic, Soundness and Completeness, Forward and Backward chaining.

Module 3 (10 hours)

Automation – Introduction - Automation in Production System, Principles and Strategies of Automation, Basic elements of an Automated System, Advanced Automation Functions, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines. (SLE: Analysis of Transfer Lines). Automated Manufacturing Systems: Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, GT and Cellular Manufacturing, FMS, FMS and its Planning and Implementation.

Module 4 (10 hours)

Control Technologies in Automation: Industrial Control Systems, Process Industries VS Discrete Manufacturing Industries, Continuous VS Discrete Control, Computer Process and its Forms. (SLE: Sensors, Actuators and other Control System Components). Computer Based Industrial Control: Introduction & Automatic Process Control, Building Blocks of Automation Systems: LAN, Analog & Digital I/O Modules, SCADA Systems & RTU. Distributed Control System - functional requirements, configurations & some popular Distributed Control Systems.

References

1. M.P.Groover , Automation*, Production Systems and Computer Integrated Manufacturing*, Pearson Education, 5th edition, 2009.
2. Krishna Kant, *Computer Based Industrial Control*,EEE-PHI,2nd edition,2010
3. Tiess Chiu Chang & Richard A. Wysk , *An Introduction to Automated Process Planning Systems*.

4. Viswanandham, *Performance Modeling of Automated Manufacturing Systems*, PHI, 1st edition, 2009.
5. Deepak Khemani, *A First Course in Artificial Intelligence*, McGraw Hill Education (India), 2013
6. Stefan Edelkamp and Stefan Schroedl. *Heuristic Search: Theory and Applications*, Morgan Kaufmann, 2011.
7. John Haugeland, *Artificial Intelligence: The Very Idea*, A Bradford Book, The MIT Press, 1985.
8. Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence,* A K Peters/CRC Press; 2 edition, 2004.
9. Zbigniew Michalewicz and David B. Fogel, *How to Solve It: Modern Heuristics*, Springer; 2nd edition, 2004.
10. Judea Pearl, Heuristics: *Intelligent Search Strategies for Computer Problem Solving*, Addison-Wesley, 1984.
11. Elaine Rich and Kevin Knight., *Artificial Intelligence*, Tata McGraw Hill, 1991.
12. Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd Edition, Prentice Hall, 2009.
13. Eugene Charniak, Drew McDermott, *Introduction to Artificial Intelligence*, Addison-Wesley, 1985.
14. Patrick Henry Winston, *Artificial Intelligence*, Addison-Wesley, 1992.

EE6491D INDUSTRIAL POWER & AUTOMATION LABORATORY -1

Pre-requisite: Nil

L	T	P	C
0	0	2	1

Total hours: 39

Course Outcomes:

CO1: Perform hands on experiments on different industrial power equipment and familiarize with it.
CO2: Explain the working of SCADA system and conduct various experiments on transmission an distribution module to learn the basic operations of SCADA.
CO3: Control AC servo motor speed, lift plant model and automatic star delta starter using programmable logic controller, dSPACE, and microcontroller.
CO5: Control pneumatic stamping system and conveyor sorting system with colour sensing fibre unit using programmable logic controller and DCS.
CO6: Perform Eexperiments on Reactive power compensation of a transmission line using STATCOM , voltage compensation using SSSC

List of Compulsory Experiments:

1. SCADA Experiments
   a) SCADA- Transmission Module RTU in Local and Remote Mode.
      a. Ferranti Effect
      b. VAR Compensation (Series and Shunt)
      c. Transmission Line Modelling
   b) SCADA- Distribution Module RTU in Local and Remote Mode.
      a. Load Shedding
      b. Transformer Loading
      c. Study of Communication Link
2. PLC Programming Experiments
   a) Lift Control
   b) Speed Control of AC Servo Motor
   c) Automatic Star Delta Starter of Three Phase Induction Motor
3. AC Servo Motor Control using dSPACE
4. Stepper Motor speed control and step angle control using 8051 Microcontroller.
5. Simulation of Pick and Place Robot in robot studio software and implementation in ABB IRB 1200
6. Distributed Control Systems application and logic operations with master and slave controllers.
7. Conveyor Sorting System with color sensing fiber unit by using PLC and DCS.
8. Stamping Process by using Programmable Logic Controller and DCS.

9. STATCOM and FACTS based Experiments.
    a) Reactive Power Compensation using solar and wind based STATCOM.
    b) Power Factor Compensation and Voltage Regulation using three phase FACTS controller.

References

1. Lab manual /, Hand books of SCADA/DCS
2. Stuart A. Boyer, *SCADA-Supervisory Control and Data Acquisition*, Instrument Society of America Publications,USA,2004
3. K. Krishnaswamy, *Process Control*, New Age International, 2007

EE6493D SEMINAR

Pre-requisite: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Course Outcomes:

CO1: Identify research papers for understanding emerging technologies in the field of Industrial Power and Automation Systems, to summarize and to review them.
CO2: Interpret promising new directions of various cutting edge technologies.
CO3: Devise skills in preparing detailed report describing the reviewed topic.
CO4: Develop the ability to communicate by making an oral presentation before an evaluation committee.

Course Outcomes:

Individual students will be asked to choose a topic in any field of Industrial Power and Automation Systems and/or relevant to industry or society, preferably from outside the M.Tech syllabus and give seminar on the topic for about thirty minutes. A committee consisting of at least three faculty members specialized on different fields of engineering will assess the presentation of the seminars and award the marks to the students. Each student will be asked to submit two copies of a write up of the seminar talk – one copy will be returned to the student after duly certifying by the Chairman of the assessing committee and the other copy will be kept in the departmental library.

EE6402D PROCESS CONTROL & AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the process modelling, process dynamics and process instrumentation

CO2: Analyze various feedback and feed forward control strategies and design the control system based on frequency response analysis.

CO3: Demonstrate the process control of MIMO systems, control loop interactions, singular value analysis, decoupling control and real time optimization.

CO4: Describe advanced control strategies – Model predictive control, Adaptive control, Inferential Control and Batch process control.

CO5: Perform plant wide control design, instrumentation for process monitoring and statistical process Control.

Module 1: (9 hours)

Process Modeling- Introduction to Process control and process instrumentation-Hierarchies in process control systems-Theoretical models-Transfer function-State space models-Time series models-Development of empirical models from process data-chemical reactor modeling-. Analysis using softwares

Module 2: (10 hours)

Feedback & Feedforward Control- Feedback controllers-PID design, tuning, trouble shooting-Cascade control- Selective control loops-Ratio control-Control system design based on Frequency response Analysis-Direct digital design-Feedforward and ratio control-State feedback control- LQR problem- Pole placement -Simulation using softwares-Control system instrumentation-Control valves- Codes and standards- Preparation of P& I Diagrams.

Module 3: (10 hours)

Advanced process control-Multi-loop and multivariable control-Process Interactions-Singular value analysis-tuning of multi loop PID control systems-decoupling control-strategies for reducing control loop interactions-Real-time optimization-Simulation using softwares

Module 4: (10 hours)

Model predictive control-Batch Process control-Plant-wide control & monitoring- Plant wide control design-Instrumentation for process monitoring-Statistical process control-Introduction to Fuzzy Logic in Process Control-Introduction to OPC-Introduction to environmental issues and sustainable development relating to process industries. Comparison of performance different types of control with examples on softwares

References

1. Seborg, D.E., T.F. Edgar, and .A. Mellichamp, *Process Dynamics and Control*, John Wiley , 2004
2. Johnson D Curtis, *Instrumentation Technology*, 7th Edition, Prentice Hall India, 2002.
3. Bob Connel, *Process Instrumentation Applications Manual*, McGrawHill, 1996.
4. Edgar, T.F. & D.M. Himmelblau, *Optimization of Chemical Processes*, McGrawHill Book Co, 1988.
5. Macari Emir Joe and Michael F Saunders, Environmental Quality Innovative Technologies and Sustainable Development, American Society of Civil Engineers, 1997.

6. Nisenfeld , A.E ,(Ed) , *Batch Control: practical guides for measurement and control*, Instrument Society of America, 1996.
7. Sherman, R.E. (Ed), *Analytical instrumentation*, Instrument Society of America, 1996.
8. Shinskey, F.G., *Process Conrol Systems: Applications, Design and Tuning* ,3rd Edition, McGrawHill Book Co, 1988.
9. B. Wayne Bequette, *Process control: modeling, design, and simulation* ,Prentice Hall PTR, 2003
10. K. Krishnaswamy, *Process Control*, New Age International, 2007

EE6406D INDUSTRIAL DRIVES & CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Acquire knowledge about various types of controlled rectifiers and harmonic and power factor analysis

CO2: Develop capability to choose a suitable Motor and Power Electronic Converter– involving load estimation, load cycle considerations, thermal aspects and motor-converter matching.

CO3: Various PWM techniques of 2-level DC to AC converters and multilevel inverters with advanced PWM techniques.

CO4: To understand the working and design of various converters used in Electrical Drives.

Module 1 Power Converters& Controllers: (10 hours)

Single Phase rectifiers with LC filter - Voltage Doubler Rectifiers- Half Controlled and Full Controlled Bridges with passive and active loads - Input Line Current Harmonics and Power Factor- Inverter Mode of Operation, Dual Converters, Circulating Current Mode and Non-Circulating Current Mode – Multilevel Inverters - PWM techniques – Hysteresis Control.

Module 2 Electric Drives : (10 hours)

Introduction to Motor Drives - Components of Power Electronic Drives - Criteria for selection of Drive components - Match between the motor and the Power Electronics converter – Characteristics of mechanical systems - DC Motor Drives - Drive transfer function – Drives control – speed controller design - Effect of armature current waveform - Torque pulsations - Adjustable speed DC drives

Module 3: AC Drives (10 hours)

Induction Motor Drives - Impact of non-sinusoidal excitation on induction motors - Variable frequency square wave and PWM VSI drives, CSI drives - Line frequency variable voltage drives - Soft start of induction motors - V/F method and static slip power recovery\ - Vector control - Synchronous Motor Drives -load commutated inverter drives.

Module 4: Advanced Drive Applications (9 hours)

PMSM Drives with electronics commutation, BLDC motor drives with Front-end converter - Switched reluctance motor Drive.
Selection of motor drive based on applications – selection of motor, power circuit, control method, switching devices, and other hardware components - drive system for robotic and space applications – drive for electric vehicle applications –drive for process industries — speed and torque sensing methods for drive.

References

1. Ned Mohan, *Power electronics : converters, applications, and design*, John Wiley and Sons, 2006
2. Dewan ; Straughen, *Power Semiconductor Circuits*, John Wiley & Sons., 1975 .
3. M.D.Singh; K.B.Khanchandani, *Power Electronics*, Tata McGraw Hill., 2007
4. B. K Bose, *Modern Power Electronics and AC Drives*, Pearson Education (Asia)., 2009
5. R Krishnan, *Electric Motor Drives, Modeling, Analysis, and Control*, Pearson Education,2001
6. G.K.Dubey & C.R.Kasaravada, *Power Electronics & Drives*, Tata McGraw Hill,1993.

EE6404D INDUSTRIAL INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the industrial measurement system and different elements involved in it.
CO2: Describe the various sensors and transducers used for different industrial variables like torque, pressure, etc.
CO3: Explain signal conditional circuits like amplifiers, filters, ADC, etc. for working industrial measurement systems.
CO4: Analyze the static and response characteristics of first order and higher order system.
CO5: Analyze the measurement systems used for servo motors.

Module 1: (11 hours)

Industrial measurement systems – different types of industrial variables and measurement systems elements – sensors and transducers for different industrial variables like pressure, torque, speed, temperature etc– sensor principles – examples of sensors – sensor scaling – Industrial signal conditioning systems- Amplifiers – Filters – A/D converters for industrial measurements systems –review of general Industrial instruments.

Module 2: (8 hours)

Calibration and response of industrial instrumentation - standard testing methods and procedures – Generalized performance characteristics – static response characterization – dynamic response characterization - zero order system dynamic response characterizations – first order system dynamic response second order system dynamic response – higher order systems - Response to different forcing functions such as step, sinusoidal etc. to zero, first, second third and higher orders of systems.

Module 3: (11 hours)

Regulators and power supplies for industrial instrumentation – linear series voltage regulators – linear shunt voltage regulators – integrated circuit voltage regulators – fixed positive and negative voltage regulators – adjustable positive and negative linear voltage regulators – application of linear IC voltage regulators - switching regulators –single ended isolated forward regulators- half and full bridge rectifiers. pH and conductivity sensors. Piezo-electric and ultrasonic sensors and its application in process and biomedical instrumentation. Measurement of viscosity, humidity and thermal conductivity

Module 4: (9 hours)

Servo drives – servo drive performance criteria – servomotors shaft sensors and coupling – sensors for servo drives – servo control loop design issues- stepper motor drives types and characteristics – hybrid stepper motor – permanent magnet stepper motor – hybrid and permanent magnet motors – single and multi step responses.

References

1. Ernest O. Doebelin *Measurement systems applications and design*, McGraw – Hill International Editions, McGraw- Hill Publishing Company, 1990
2. Patric F. Dunn University of Notre Dame, *Measurement and Data Analysis for engineering and science*, Mc Graw Hill Higher education, 1995

3. Randy Frank, *Understanding Smart Sensors*, Artec House Boston. London, 2000
4. Muhamad H Rashid, *Power electronics handbook*, ACADEMIC PRESS, 2007
5. K Krishnaswamy, *Industrial Instrumentation*, New Age International Publishers, New Delhi, 2003
6. Gregory K. McMillan, Douglas M. Considine , *Process/Industrial Instruments and Controls Handbook*,5th Edition, Mc Graw Hill 1999
7. Steve Mackay, Edwin Wright, John Park, *Practical Data Communications for Instrumentation and Control*, Newness Publications, UK, 2003
8. John O Moody, Paros J Antsaklis, *Supervisory Control of discrete event systems using petrinets*, PHI, 2002
9. James L Peterson, *Petrinet theory and modeling of system*, 1981

EE6494D MINI PROJECT

Pre-requisite: Nil

L	T	P	C
0	0	3	2

Total hours: 26

Course Outcomes:

CO1: To develop skill sets to take up projects through identifying problem formulation, methodology and outcome for giving solutions to small industrial technical problems.

CO2: To pursue a project under a topic of interest in the area of Industrial Power & Automation through literature search, design, numerical computations and hardware implementation.

CO3: To get trained on new technologies/tools to resolve industrial problems which is cost-effective with a scope of product development.

CO4: Through presentation/ hardware demonstration, effectively share the knowledge learned/ solutions for the identified problem and write technical report about the work for publications in peer reviewed conferences/journals.

Each student should identify a topic in the area of Industrial Power &Automation, which can be done as a project within one semester time span under the guide ship of any faculty of electrical engineering department. He/she can have additional guides from other department/institutions/industries also. Student has to identify problem formulation, objectives, methodology and probable outcome with Gantt chart. Student can pursue on the same once the topic and the evaluation committee approves objectives. Student can utilize the laboratory setups, softwares available in any of the laboratories inside the campus. In addition, they can take necessary data/information from industries/other technical institutions to improve the standard of the work. After the completion, they have to give oral presentations with hardware demonstration at the end of the semester that would be evaluated by the expert evaluation committee. In addition, there will be review presentations to assess the progress of the work during the semester. Once the committee approves the work, student can submit a detailed report in the prescribed format and get it duly signed by guide and chair of the evaluation committee. The student will be assessed upon the technical contributions to resolve the problem identified.

EE6492D INDUSTRIAL POWER & AUTOMATION LABORATORY -2

Pre-requisite: Nil

L	T	P	C
0	0	2	1

Total hours: 39

Course Outcomes:

CO1: Perform hands on experiments on different industrial power and automation equipment and familiarize with it.
CO2: Control batch process reactor using programmable logic controller.
CO3: Control the speed of AC, DC and BLDC Motors using digital signal processor.
CO4: Perform experiments on Vector control drive for SRM using FPGA.
CO5: Simulate the response of a DC motor based on the mathematical model derived from the physical model of the system using LabVIEW.
CO6**:** Develop a real time program in LabVIEW and run it on real time hardware target using compact field point.

List of Compulsory Experiments:

1. PLC Programming Experiments
    1. Water Level Control
    2. Control of Batch Process Reactor

2. DSP Programming Experiments

a. Speed control of BLDC motor (2812/2407 kit)
b. Speed control of Induction motor (2812/2407 kit).
c. Speed control of DC motor (2812/2407 kit).

3. Vector control drive for SRM using FPGA.
4. Level Control of tank using Cascade Controller.
5. Level Control of tank using Split Range Controller.
6. Feed forward Control for various disturbances in the temperature process control.
7. MIMO system for multiple level, flow and temperature controls.
8. Experiments on LabVIEW and MATLAB.
    1. State Space Modeling of DC motor in MATLAB and LabVIEW.
    2. PID, fuzzy and fuzzy-PID controller based speed control of dc motor in MATLAB.
    3. PID Controller based speed control of DC motor in LabVIEW.

Reference

1. Lab manual /, Hand books of DCS
2. K. Krishnaswamy, *Process Control*, New Age International, 2007

EE7491D PROJECT PART - 1

Pre-requisite: A student should have registered for all theory and laboratory courses in the first and second semester of the program and secured a grade other than 'W'.

L	T	P	C
0	0	30	10

Total hours: 364

Course Outcomes:

CO1: Develop comprehensive solution to issues identified in previous semester work and meet the requirements as stated in project proposal

CO2: Compile the results of the detailed analytical studies conducted and interpret the results for application to the instrumentation and control system.

CO3: Summarize the results and effectively communicate the research contribution and publish in reputed Journals /Conference.

Each student should identify a topic in the area of Industrial Power & Automation, which can be done as a project with in one semester time span under the guide ship of any faculty of electrical engineering department. He/she can have additional guides from other department/institutions/industries also. The problem identified should have sufficient quantity of work to be done in the 4^{th} semester also as Project – Part 2. Student has to identify problem formulation, objectives, methodology and probable outcome with Gantt chart spanning over one year. Student can pursue on the same once the topic and the evaluation committee approves objectives. Student can utilize the laboratory setups, softwares available in any of the laboratories inside the campus. In addition, they can take necessary data/information from industries/other technical institutions to improve the standard of the work. After the completion, they have to give oral presentations with experimental demonstration at the end of the semester that would be evaluated by the expert evaluation committee. In addition, there will be review presentations to assess the progress of the work during the semester. Once the committee approves the work, student can submit a detailed report in the prescribed format and get it duly signed by guide and chair of the evaluation committee. The student will be assessed upon the technical contributions to resolve the problem identified.

EE7493D INDUSTRIAL TRAINING/INTERNSHIP

Pre requisites: Nil

L	T	P	C
0	0	0	1

Course outcomes:

CO1: Understand the vibrant atmosphere prevailing in an industry/project site.
CO2: Explain different processes in Industry.
CO3: Identify the roles of the management & administrative, non-technical operations/divisions in an Industry.
CO4: Recognize issues/problems in the industry and suggest improvements/solutions.
CO5: Adapt with the etiquette/mannerism/self-discipline followed by professionals.
CO6: Develop the skill to manage people in an industry.

Industrial Training shall be completed during summer vacation and will be credited in 3rd semester along with project –part 1.

Minimum Duration of the industrial training shall be 20 days in a reputed industry**.** Training should be focussed on the familiarization with the dynamic environment in an industry to identify issues/problems and suggest improvements/solutions.

Course Assessment Methods:
Students will select a reputed industry for the training from the approved list of industries. During the training, students shall make a detailed study of the plant/process, identify a specified area/process which needs improvements, he/she shall go in detail in the selected process with hands on experience, identify the problems and solutions for improvements, discuss with the plant engineers/officials, if possible, implement the suggested solution /improvement, conclude and report to plant manager. A certificate from the plant officials shall be enclosed with the report.

Evaluation : 100 marks
(Understanding the plant process, Problem identification, Solution strategies, Suggestions from plant officials, Implementation steps: 70 marks
Presentation, results, report, outcome: 30 marks)

EE7492D PROJECT PART - 2

Pre-requisite: EE7491D PROJECT PART – 1

L	T	P	C
0	0	30	14

Total hours: 364

Course Outcomes:

CO1: Develop comprehensive solution to issues identified in previous semester work and meet the requirements as stated in project proposal

CO2: Compile the results of the detailed analytical studies conducted and interpret the results for application to the instrumentation and control system.

CO3: Summarise the results and effectively communicate the research contribution and publish in reputed Journals /Conference.

EE7492D PROJECT PART -2 is a continuation of EE7491D PROJECT PART-1 in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their research contributions in reputed conferences and/or journals. The project evaluation committee of the M. Tech program shall assess the project work during the fourth semester in two stages. Two internal evaluations shall be conducted in the department level followed by final viva-voce examination by the committee including an external examiner. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the project evaluation committee. The students shall submit both soft and hard copies (required number of copies) of project report in the prescribed format to the department and library after incorporating all the corrections and changes suggested by the project evaluation committee.

EE6421D SMART GRID TECHNOLOGIES AND APPLICATIONS

Prerequisites: Fundamentals of Power Distribution Systems

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain various smart resources, smart meters and other smart devices.
CO2: Describe modern power distribution system functions.
CO3: Identify suitable communication networks for smart grid applications

Module 1 (8 hours)

Introduction - Evolution of Electric Grid, Smart Grid Concept - Definitions and Need for Smart Grid – Functions – Opportunities – Benefits and challenges, Difference between conventional & Smart Grid,Technology Drivers.

Module 2 (11 hours)

Energy Management System (EMS) - Smart substations - Substation Automation - Feeder Automation, SCADA – Remote Terminal Unit – Intelligent Electronic Devices – Protocols, Phasor Measurement Unit – Wide area monitoring protection and control, Smart integration of energy resources – Renewable, intermittent power sources – Energy Storage.

Distribution Management System (DMS) – Volt / VAR control – Fault Detection, Isolation and Service Restoration, Network Reconfiguration, Outage management System, Customer Information System, Geographical Information System, Effect of Plug in Hybrid Electric Vehicles.

Module 3 (9 hours)

Introduction to Smart Meters – Advanced Metering infrastructure (AMI), AMI protocols – Standards and initiatives, Demand side management and demand response programs, Demand pricing and Time of Use, Real Time Pricing, Peak Time Pricing.

Module 4 (11 hours)

Elements of communication and networking – architectures, standards, PLC, Zigbee, GSM, BPL, Local Area Network (LAN) - House Area Network (HAN) - Wide Area Network (WAN) - Broadband over Powerline (BPL) - IP based Protocols - Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid

References

1. Stuart Borlase , *Smart Grid: Infrastructure, Technology and Solutions*, CRC Press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, *Smart Grid: Technology and Applications*, Wiley, 2012.
3. Mini S. Thomas, John D McDonald, *Power System SCADA and Smart Grids*, CRC Press, 2015
4. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, *Communication Networks for Smart Grids*, Springer, 2014.

EE6422D ENGINEERING OPTIMIZATION AND ALGORITHMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply mathematical and numerical techniques of optimization theory to concrete Engineering problems.
CO2: Create, solve and analyze the optimization problems.
CO3: Describe the mathematical properties of general linear programming problems and obtain the solution of linear programming problems using appropriate techniques.
CO4: Formulate real-world problems as Linear Programming models, apply the simplex method and dual simplex algorithms in solving the standard LP problem and interpret the results obtained.
CO5: Apply linear programming in various engineering applications
CO6: Identify solution algorithms to find the best possible solution in nonlinear decision models.

Module 1: (10 hours)

Concepts of optimization: Engineering applications-Statement of optimization problem-Classification - type and size of the problem.
Classical Optimization Techniques: Single and multi variable problems-Types of Constraints .Semi definite case-saddle point.
Linear programming: Standard form-Geometry of LP problems-Theorem of LP-Relation to convexity - formulation of LP problems - simplex method and algorithm -Matrix form- two phase method.
Duality-dual simplex method- LU Decomposition. Sensitivity analysis .Artificial variables and complementary solutions-QP.
Engineering Applications: Minimum cost flow problem, Network problems-transportation, assignment & allocation, scheduling. Karmarkar method-unbalanced and routing problems

Module 2: (10 hours)

Nonlinear programming: Non linearity concepts-convex and concave functions- non-linear programming - gradient and Hessian.
Unconstrained optimization: First & Second order necessary conditions-Minimisation & Maximisation-Local & Global convergence-Speed of convergence.
Basic decent methods: Fibonacci & Golden section search - Gradient methods - Newton Method-Lagrange multiplier method - Kuhn-tucker conditions . Quasi-Newton method- separable convex programming - Frank and Wolfe method, Engineering Applications.

Module 3: (9 hours)

Nonlinear programming- Constrained optimization: Characteristics of constraints-Direct methods-SLP,SQP-Indirect methods-Transformation techniques-penalty function-Langrange multiplier methods-checking convergence- Engineering applications

Module 4: (10 hours)

Dynamic programming: Multistage decision process- Concept of sub optimization and principle of optimality- Computational procedure- Engineering applications.
Genetic algorithms- Simulated Annealing Methods-Optimization programming, tools and Software packages.

References

1. David G Luenberger, *Linear and Non Linear Programming*., 2nd Ed, Addison-Wesley Pub.Co.,Massachusetts, 2003.
2. W.L.Winston, *Operation Research-Applications & Algorithms*, 2nd Ed., PWS-KENT Pub.Co.,Boston, 2007.

3. S.S.Rao, *Engineering Optimization,* 3rd Ed.,New Age International (P) Ltd,New Delhi, 2007.
4. W.F.Stocker, *Design of Thermal Systems*, 3rd Ed., McGraw Hill, New York. 1990.
5. G.B.Dantzig, *Linear Programming and Extensions*, Princeton University Press, N.J., 1963.
6. L.C.W.Dixton, *Non Linear Optimisation: theory and algorithms*, Birkhauser, Boston, 1980.
7. Bazarra M.S., Sherali H.D. & Shetty C.M, *Nonlinear Programming Theory and Algorithms*, John Wiley,New York,1979.
8. A. Ravindran, K. M. Ragsdell, G. V. Reklaitis, *Engineering Optimization: Methods And Applications*, Wiley, 2008.
9. Godfrey C. Onwubolu, B. V. Babu, *New optimization techniques in engineering*, Springer, 2004.
10. Kalyanmoy Deb, *Optimisation for Engineering Design-Algorithms and Examples*, Prentice Hall India 1998.

EE6423D INDUSTRIAL COMMUNICATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:
CO1: Develop a comprehensive understanding of the industrial data communication systems.
CO2: Explain inter-networking and serial communications.
CO3: Explain common principles, various standards and protocol stack in networking
CO4: Summarize on industrial Ethernet and wireless communication.
CO5: Explain the SCADA communication network and other open standard communication Protocols.

Module 1: (10 hrs)

Characteristics of Communication Networks- Traffic characterisation and Services- Circuit Switched and Packet Switched Networks- Virtual circuit Switched networks- OSI Model- Protocol Layers and Services- The physical layer-Theoretical basis for data communication- signalling and modulation-multiplexing-Transmission media-Physical interface and protocols

Module 2: (9 hrs)

The transport layer- Connectionless transport-UDP –TCP- Congestion control - Network layer series and routing- internet protocol (IP) - Network layer addressing- hierarchical addresses-address resolution-services- Datagram- virtual circuits- routing algorithm (Bellman Ford,Dijkstra)

Module 3: (10 hrs)

Direct link Networks: Framing; Error detection; Reliable transmission; Multiple access protocols; Concept of LAN- Ethernet LAN – Ethernet frame structure-Ethernet (IEEE 802.3); Token Rings (IEEE 802.5 & FDDI); Address Resolution Protocol- IEEE 802.11 LAN's- architecture and media access protocols, hubs, bridges, switches, PPP, ATM, wireless LAN

Module 4: (10 hrs)

Introduction to industrial networks – SCADA networks - Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED) - Communication Network, SCADA Server, SCADA/HMI Systems - single unified standard architecture -IEC 61850 - SCADA Communication: various industrial communication technologies -wired and wireless methods and fiber optics, open standard communication protocols

References

1. Karanjith S.Siyan, *Inside TCP/IP*., 3rd edition, Techmedia, 1998
2. Alberto,Leon,Garcia, Indra, and Wadjaja, *Communication networks* , Tata Mc Graw Hill,2000
3. James F Kurose.Keith W Ross, *Computer networking A Top down Approach featured internet*, Pearson Education, 2003.
4. Keshav*, An engineering approach to computer networking*, Addison-Wesley, 1999
5. Radia Perlmal, *Interconnections* , 2nd edition, Addison Wesley, 2000
6. Douglas E comer, *Inter networking with TCP/IP*, Vol 1, Prentice Hall India, 1999.
7. Andrew S. Tannebaum, *Computer Networks*., Fourth Edition., Prentice Hall,2003
8. Stuart A. Boyer, *SCADA-Supervisory Control and Data Acquisition, Instrument Society of America Publications*,USA,1999.
9. Gordon Clarke, Deon Reynders, *Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems*, Newnes Publications, Oxford, UK,2004.

10. Afritech Panel, *Industrial communication*, Afritech, 2006
11. Michael William Ivens, The practice of industrial communication, Business Publications, 1963
12. Richard Zurawski, The industrial communication technology handbook, CRC Press, 2005
13. Raimond Pigan, Mark Metter, Automating with PROFINET: Industrial Communication Based on Industrial Ethernet, Publishing 2008

EE6424D ROBOTIC SYSTEMS AND APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:
CO1: Apply the mathematics of spatial descriptions and transformations
CO2: Explain the robot system components that combines embedded hardware, software and mechanical systems.
CO3: Describe manipulator kinematics and mechanics of robotic motion.
CO4: Explain the manipulator dynamics, transformation of acceleration, and robot controller architecture
CO5: Apply artificial intelligence techniques in robotics
CO6: Explain various robotics applications and their associated components and control systems.

Module 1: (8 hours)

Mathematics of Spatial Descriptions and Transformations-Robot definition. Robot classification. Robotic system components- Notations- Position definitions- Coordinate frames - Different orientation descriptions - Free vectors- Translations, rotations and relative motion - Homogeneous transformations.

Module 2: (10 hours)

Manipulator Kinematics and Mechanics of Robot Motion-Link coordinate frames- Denavit-Hartenberg convention - Joint and end-effector Cartesian space-Forward kinematics transformations of position-Inverse kinematics of position-Translational and rotational velocities -Velocity Transformations-Manipulator Jacobian -Forward and inverse kinematics of velocity-Singularities of robot motion-Static Forces-Transformations of velocities and static forces -Joint and End Effector force/torque transformations-Derivation for two link planar robot arm as example.

Module 3: (12 hours)

Manipulator Dynamics- Transformations of acceleration- Trajectory Planning- Control-Lagrangian formulation- Model properties - Newton-Euler equations of motion- Derivation for two link planar robot arm as example- Joint space-based motion planning - Cartesian space-based path planning-Independent joint control- Feed-forward control-Inverse dynamics control-Robot controller architectures. Implementation problems.

Module 4: (9 hours)

Robot Sensing and Vision Systems- Sensors-Force and torque sensors-low level vision-high level vision-Robot Programming languages-Introduction to Intelligent Robots-Robots in manufacturing automation.

References

1. Fu, K.S., R.C. Gonzalez, C.S.G. Lee, *Robotics: Control, Sensing, Vision & Intelligence*, McGrawHill, 1987.
2. Craig, John J., Introduction *to Robotics: Mechanics & Control*, 2nd Edition, Pearson Education, 1989.
3. Gray J.O., D.G. Caldwell(Ed), *Advanced Robotics & Intelligent machines*, The Institution of Electrical Engineers, UK, 1996.
4. Groover, Mikell P, *Automation, Production Systems & Computer Integrated manufacturing*, Prentice hall India, 1996.
5. Groover Mikell P., M. Weiss, R.N. Nagel, N.G. Odrey, *Industrial Robotics*, McGrawHill, 1986.
6. Janakiraman, P.A*., Robotics & Image Processing*, Tata McGrawHill, 1995.

7. Sciavicco, L., B. Siciliano, *Modelling & Control of Robot Manipulators*, 2nd Edition, Springer Verlag, 2000.
8. Robin R. Murphy, *An introduction to AI Robotics*, MIT Press, 2008
9. Oliver Brock, Jeff Trinkle and Fabio Ramos, *Robotics-Science and Systems*, Vol. IV, MIT Press 2009

EE6425D SUSTAINABLE ENERGY SYSTEMS & DESIGN

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply principles and values of sustainable energy design to a range of settings

CO2: Analyse and evaluate social, environmental and economic impacts and constraints relating to sustainable energy design solutions

CO3: Develop designs for a range of innovative sustainable energy solutions (consistent with these principles) to meet a given end-use energy demand

Module 1: (10 hours)

Energy modeling:-

World energy use – Reserves of energy resources – Environmental aspects of energy utilization-Renewable energy scenario in India – Potentials – Achievements – Applications. Input output analysis, energy demand analysis and forecasting, economics of standalone power supply systems. Methodology for Energy Demand Analysis – Methodology for Energy Technology. Forecasting-Methodology for Energy Forecasting-Sectoral Energy Demand Forecasting. Energy Economics and Policies: National and Sectoral energy planning; Integrated resources planning; Energy pricing.

Module 2: (11 hours)

New Energy Sources: Impact of thermal, gas, hydro and nuclear power stations on environment. Green House Effect (Global Warming). Renewable and non-renewable energy sources. Conservation of natural resources and sustainable energy systems. Indian energy scene. Introduction to electric energy generation by wind, solar and tidal.

Solar-Solar energy – The Sun – Production and transfer of solar energy – Sun-Earth angles – Availability and limitations of solar energy – Measuring techniques and estimation of solar radiation – Solar thermal collectors – General description and characteristics – Flat plate collectors – Heat transfer processes – Short term and long term collector performance – Solar concentrators – Design, analysis and performance evaluation.

Module 3: (9 hours)

Energy from biomass – Sources of biomass – Different species – Conversion of biomass into fuels – Energy through fermentation – Pyrolysis, gasification and combustion – Aerobic and anaerobic bio-conversion – Properties of biomass – Biogas plants – Types of plants – Ethanol production – Bio diesel –Design and operation – Cogeneration – Biomass applications. Properties and characteristics of biogas.

Module 4: (9 hours)

Wind energy – Principles of wind energy conversion – Site selection considerations – Wind power plant design – Types of wind power conversion systems – Operation, maintenance and economics – Geothermal energy – Availability, system development and limitations – Ocean thermal energy conversion – Wave and tidal energy – Scope and economics – Introduction to integrated energy systems.

References:

1. J.A. Duffie and W.A. Beckman, *Solar Energy thermal processes*, J. Wiley, 1994.

2. A.A.M. Saigh, *Solar Energy Engineering*, Academic Press, 1977.
3. F. Kreith and J.F. Kreider, *Principles of Solar Engineering*, McGraw Hill, 1978.
4. G.N. Tiwari, *Solar Energy-Fundamentals, Design, Modelling and Applications*, Narosa Publishers, 2002.
5. Ahmed, *Wind energy Theory and Practice*, PHI, Eastern Economy Edition, 2012.
6. H.P. Garg, S.C. Mullick and A.K. Bhargava, *Solar Thermal Energy Storage*, Springer Netherland, 1985.
7. K.M. Mittal, *Non-conventional Energy Systems-Principles, Progress and Prospects*, Wheeler publications, 1997.
8. Kothari, *Renewable Energy Sources and Emerging Technologies*, PHI, Eastern Economy Edition, 2012.

EE6426D DISTRIBUTION SYSTEMS MANAGEMENT AND AUTOMATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Describe the architecture, functions and implementation strategies of Distribution Automation Systems and Distribution Management Systems.
CO2: Apply Custom power devices for improving power quality and explain the issues related to the integration of Distributed Generation and Custom Power components in a distribution system.
CO3: Evaluate the performance of electrical distribution system on the basis of reliability indices calculation.
CO4: Perform electrical distribution system design for industrial and commercial buildings with emphasis given to Electrical Safety and Earthing Practices.
CO5: Describe the wireless and wired communication systems, communication protocols and architectures for control and automation of Distribution system.
CO6: Explain deregulated power system.

Module 1: (10 Hours)

Distribution Automation System: Necessity, System Control Hierarchy- Basic Architecture and implementation Strategies for DA- Basic Distribution Management System Functions- Outage management-

Integration of Distributed Generation and Custom Power components in distribution systems- Distribution system Performance and reliability calculations

Module 2: (9 Hours)

Electrical System Design: Distribution System Design- Electrical Design Aspects of Industrial, Commercials Buildings- Electrical Safety and Earthing Practices at various voltage levels- IS Codes

Module 3: (11 Hours)

Communication Systems for Control and Automation- Wireless and wired Communications- DA Communication Protocols, Architectures and user interface-Case Studies

Module 4: (9 Hours)

Power Quality and Custom Power: Concept- Custom Power Devices - Operation and Applications

Deregulated Systems: Reconfiguring Power systems- Unbundling of Electric Utilities- Competition and Direct access

References

1. James Northcote – Green, Robert Wilson, *Control and Automation of Electrical Power Distribution Systems* , CRC Press, New York, 2007.
2. Turan Gone, *Electric Power Distribution System Engineering* , McGraw Hill Company. 1986.
3. M.V Deshpande , *Electrical Power System Design* , Tata-McGraw Hill, 1966.
4. IEEE Press: *IEEE Recommended practice for Electric Power Distribution for Industrial Plants*, published by IEEE, Inc., 1993
5. Pansini, *Electrical Distribution Engineering*, The Fairmont Press, Inc., 2007

6. IEEE Standerd 739 . Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities. 1984
7. G H Heydt , *Electric Power Quality* , McGram Hill, 2007
8. Wilson K. Kazibwe and Musoke H Semdaula , *Electric Power Quality Control Techniques,* Van Nostarand Reinhold New York, 2006
9. Lakervi & E J Holmes , *Electricity distribution network design*, 2nd Edition Peter Peregrimus Ltd. 1995

EE6428D SCADA SYSTEMS & APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Describe the basic tasks of Supervisory Control Systems (SCADA) as well as their typical applications.
CO2: Explain SCADA architecture and SCADA system components
CO3: Describe the single unified standard architecture IEC 61850
CO4: Explain SCADA communication system, various industrial communication technologies and open standard communication protocols.
CO5: Apply SCADA systems in transmission and distribution sectors and industries.

Module 1: (10 hours)

Introduction to SCADA: Data acquisition systems, Evolution of SCADA, Communication technologies, Monitoring and supervisory functions, SCADA applications in Utility Automation, Industries

Module 2: (10 hours)

SCADA System Components: Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Programmable Logic Controller (PLC), Communication Network, SCADA Server, SCADA/HMI Systems

Module 3: (10 hours)

SCADA Architecture: Various SCADA architectures, advantages and disadvantages of each system - single unified standard architecture - IEC 61850. SCADA Communication: various industrial communication technologies -wired and wireless methods and fiber optics. Open standard communication protocols

Module 4: (9 hours)

SCADA Applications: Utility applications- Transmission and Distribution sector -operations, monitoring, analysis and improvement. Industries - oil, gas and water. Case studies, Implementation, Simulation Exercises

References

1. Stuart A. Boyer, *SCADA-Supervisory Control and Data Acquisition*, Instrument Society of America Publications,USA,2004.
2. Gordon Clarke, Deon Reynders, *Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems*, Newnes Publications, Oxford, UK,2004.
3. William T. Shaw, *Cybersecurity for SCADA systems*, PennWell Books, 2006
4. David Bailey, Edwin Wright, *Practical SCADA for industry*, Newnes, 2003
5. Michael Wiebe, *A guide to utility automation: AMR, SCADA, and IT systems for electric power*, PennWell 1999.

EE6429D WIRELESS & SENSOR NETWORKS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Apply the knowledge of wireless sensor networks(WSN) to various application areas.
CO2: Design and implement WSN.
CO3: Conduct performance analysis of WSN and manage WSN.
CO4: Formulate and solve problems creatively in the area of WSN.

Module 1 (11 hours)

Introduction: Introduction to Sensor Networks, unique constraints and challenges, Advantage of Sensor Networks, Applications of Sensor Networks, Mobile Adhoc NETworks (MANETs) and Wireless Sensor Networks, Enabling technologies for Wireless Sensor Networks. Sensor Node Hardware and Network Architecture: Single-node architecture, Hardware components & design constraints, Operating systems and execution environments

Module 2 (10 hours)

Introduction to TinyOS and nesC - Network architecture, Optimization goals and figures of merit, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts. Deployment and Configuration: Localization and positioning, Coverage and connectivity, Single-hop and multi-hop localization, self configuring localization systems, sensor management

Module 3 (10 hours)

Network Protocols: Issues in designing MAC protocol for WSNs, Classification of MAC Protocols, S-MAC Protocol, B-MAC protocol, IEEE 802.15.4 standard and Zig Bee, Dissemination protocol for large sensor network. Routing protocols: Issues in designing routing protocols, Classification of routing protocols, Energy-efficient routing, Unicast, Broadcast and multicast, Geographic routing.

Module 4 (8 hours)

Data Storage and Manipulation: Data centric and content based routing, storage and retrieval in network, compression technologies for WSN, Data aggregation technique. Applications: Detecting unauthorized activity using a sensor network, WSN for Habitat Monitoring.

References

1. Holger Kerl, Andreas Willig, *Protocols and Architectures for Wireless Sensor Network*, John Wiley and Sons, 2005 (ISBN: 978-0-470-09511-9).
2. Raghavendra, Cauligi S, Sivalingam, Krishna M., Zanti Taieb, *Wireless Sensor Network*, Springer 1st Ed. 2004 (ISBN: 978-4020-7883-5).
3. Feng Zhao, Leonidas Guibas, *Wireless Sensor Network* ,Elsevier, 1st Ed. 2004 (ISBN: 13- 978-1-55860-914-3)
4. Kazem, Sohraby, Daniel Minoli, Taieb Zanti, *Wireless Sensor Network: Technology, Protocols and Application* , John Wiley and Sons 1st Ed., 2007 (ISBN: 978-0-471-74300-2).
5. B. Krishnamachari, *Networking Wireless Sensors*, Cambridge University Press.
6. N. P. Mahalik, *Sensor Networks and Configuration: Fundamentals, Standards, Platforms, and Applications*, Springer Verlag.

EE6430D NETWORK & DATA SECURITY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Discuss about information security governance, and related legal and regulatory issues
CO2: Identify external and internal security threats to an organization
CO3: To be familiar with information security awareness and a clear understanding of its importance
CO4: Discover and analyze the threats to an organization and select suitable solution strategies.

Module 1: (10 hours)

Introduction: Basic objectives of cryptography, secret-key and public-key cryptography, Block ciphers: Modes of operation, DES and its variants, AES, linear and differential cryptanalysis, stream ciphers, message digest algorithms: properties of hash functions, MD5 and SHA-1, keyed hash functions, attacks on hash functions.

Module 2: (11 hours)

Modular arithmetic, gcd, primality testing, Chinese remainder theorem, finite fields. Intractable problems: Integer factorization problem, RSA problem, discrete logarithm problem, DiffieHellman problem, Publickey encryption: RSA, Elliptic curve cryptography. Key exchange: Diffie-Hellman algorithms. Digital signatures: RSA, DSS, DSA, ECDSA, blind signatures, threshold cryptography, key management.

Module 3:(13 hours)

Network Security – Electronic Mail Security- Pretty Good Privacy – S/MIME – IP security – overview and architecture – authentication header – encapsulating security payload – combing security associations – web security requirements Secure Socket Layer and Transport Layer Security – secure electronic transactions, Authentication applications: X-509, Kerberos, RADIUS.

Module 4: (5 hours)

Wireless network security - WEP, WPA2 (802.11i), security in Bluetooth.

References

1. Stallings, W., *Cryptography and network security: principles and practice,.* 4th ed. Upper Saddle River: Prentice Hall, 2006.
2. Stallings, *Network security essentials applications and standards* , Pearson education, 1999.
3. Menezes, A. J., Van Oorschot, P. C.; Vanstone, S. A., *Handbook of applied cryptography* , Boca Ratón [etc.]: CRC Press, 1997.
4. Stajano, F*., Security for ubiquitous computing* , Chichester: John Wiley and Sons, 2002.

EE6432D ADVANCED ALGORITHMS & DATA STRUCTURE ANALYSIS

Pre-requisite: Basics of Programming

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain algorithmic techniques such as brute force, greedy, and divide and conquer.
CO2: Apply advanced abstract data type (ADT) and data structures in solving real world problems.
CO3: Devise complete algorithmic solution to a given problem effectively combining the fundamental data structures and algorithmic techniques.

Module 1 (9 hours)
Review of order notation & growth of functions, recurrences, probability distributions, Average case analysis of algorithms, Basic data structures such as stacks, queues, trees, graphs linked lists, and applications, priority queues.

Module 2 (8 hours)

Direct access tables and hash tables, hash functions and relates analysis, Binary Search trees and Operations, AVL Trees and balancing operations, R B Trees, properties, operations. Dynamic Graphs, Strings, Succinct. Dynamic optimality, Memory hierarchy.

Module 3 (11 hours)

Quick sort randomized version, searching in linear time, More graph algorithms – maximal independent sets, colouring vertex cover, introduction to perfect graphs.

Module 4 (11 hours)

Algorithmic paradigms Greedy Strategy, Dynamic programming, Backtracking, Branch-and-Bound, Randomized algorithms. Generic programming methodology and algorithm design – microprogramming - ADC, Quantization, word length issues, floating point numbers, etc

References

1 H. S. Wilf, *Algorithms and complexity*, Prentice hall, 1994
2 T. H. Cormen, C. E. Leiserson, R. L. Rivest, *Introduction to Algorithms*, MIT press, 2009.

EE6434D INTERNET OF THINGS AND APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39 Hrs

Course Outcomes:
CO1: Discover the application areas of IOT ·
CO2: Realize the revolution of Internet in Mobile Devices, Cloud & Sensor Networks ·
CO3: Describe the building blocks of Internet of Things and characteristics
CO4: Explain cloud based sensor data analysis

Module 1: (10 Hours)

Elements of an IoT ecosystem. Technology drivers, Business drivers. Typical IoT applications. Trends and implications. Overview of IoT supported Hardware platforms such as: Raspberry pi, ARM Cortex Processors, Arduino and Intel Galileo boards. IoT architecture: History of IoT, M2M - Machine toMachine, Web of Things, IoT protocols. Internet of Things (IoT) and Web of Things (WoT). Internet and Web Layering

Business aspects of the Internet of Things. Representational State Transfer (REST) and Activity Streams, Business Cases & Concepts Persuasive Technologies & Behavioral Change IoT Communication Protocols Big Data and Semantic Technologies

Module 2: (10 Hours)

Overview and working principle of Wired Networking equipment - Router, Switches, Overview and working principle of Wireless Networking equipment – Access Points, Hubs, etc. Linux Network configuration concepts: Networking configurations in Linux Accessing Hardware & Device Files interactions.

Module 3: (12 Hours)

Network Fundamentals: Anatomy of a Sensor Network, Examples of Sensor Networks, Topology of a Sensor Network Communication Media. Wired Networks, Wireless Networks, Hybrid Networks. Types of Sensor Nodes, How Sensors Measure Storing Sensor Data. XBee Primer, Building an XBee-ZB Mesh Network, Arduino-Based Sensor Nodes, Hosting Sensors with Raspberry Pi

Module 4: (IoT tutorial and mini-project) (7 Hours)

Storing Sensor Data, Storage Methods - Local Storage Options for the Arduino, Local Storage Options for the Raspberry Pi, Remote Storage Options, MySQL
Local processing on the sensor nodes.

- Connecting devices at the edge and to the cloud.
- Processing data offline and in the cloud.
- Mini-project: Designing an IoT system

References

1. J. Biron and J. Follett, *Foundational Elements of an IoT Solution* , O'Reilly Media, 2016.
2. Keysight Technologies, *The Internet of Things: Enabling Technologies and Solutions for Design and Test*, Application Note, 2016.
3. Charles Bell, *Beginning Sensor Networks with Arduino and Raspberry Pi* , Apress, 2013.
4. D. Evans, *The Internet of Things: How the Next Evolution of the Internet Is Changing Everything* , Cisco Internet Business Solutions Group, 2011

5. McKinsey&Company, *The Internet of Things: Mapping the value beyond the hype* , McKinsey Global Institute, 2015
6. European Alliance for Innovation (EAI), *Internet of Things: Exploring the potential* , Innovation Academy Magazine, Issue No. 03, 2015
7. Digital Greenwich, *Greenwich Smart City Strategy* , 2015
8. ITU and Cisco, *Harnessing the Internet of Things for Global Development* , A contribution to the UN broadband commission for sustainable development

EE6436D INDUSTRIAL LOAD MODELLING & CONTROL

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain the load control techniques in industries and its application.
CO2: Explain different types of industrial processes and optimize the process using tools like LINDO and LINGO.
CO3: Apply load management technique to reduce the demand of electricity during peak time.
CO4: Analyse different energy saving opportunities in industries.
CO5: Apply the techniques of reactive power control in industries and analyze different power factor improvement methods.
CO6: Explain the mathematical modelling and profiling of various loads such as cool storage, cooling and heating loads.

Module 1: (10 hours)

Electric Energy Scenario-Demand Side Management-Industrial Load Management; Load Curves-Load Shaping Objectives-Methodologies-Barriers; Classification of Industrial Loads- Continuous and Batch processes -Load Modelling; Electricity pricing – Dynamic and spot pricing -Models;

Module 2: (10 hours)

Direct load control- Interruptible load control; Bottom up approach- scheduling- Formulation of load models-optimisation and control algorithms - Case studies;

Reactive power management in industries-controls-power quality impacts-application of filters;

Module 3: (10 hours)

Cooling and heating loads- load profiling- Modeling- Cool storage-Types-Control strategies-Optimal operation-Problem formulation- Case studies;

Module 4: (9 hours)

Captive power units- Operating and control strategies- Power Pooling- Operation models; Energy Banking-Industrial Cogeneration; Selection of Schemes Optimal Operating Strategies-Peak load saving-Constraints-Problem formulation- Case study; Integrated Load management for Industries;

References

1 C.O. Bjork , *Industrial Load Management - Theory, Practice and Simulations*, Elsevier, the Netherlands, 1989.
2. C.W. Gellings and S.N. Talukdar*, Load management concepts*. IEEE Press, New York, 1986, pp. 3-28.
3. Various Authors, *Demand side management - Alternatives*, IEEE Proceedings on DSM , Oct 1985
4. Y. Manichaikul and F.C. Schweppe , *Physically based Industrial load*, IEEE Trans. on PAS, April 1981
5. H. G. Stoll*, Least cost Electricity Utility Planning* , Wiley Interscience Publication, USA, 1989.
6. I.J.Nagarath and D.P.Kothari, *Modern Power System Engineering* , Tata McGraw Hill publishers, New Delhi, 1995.
7. Cogeneration as a means of pollution control and energy efficiency in Asia 2000. Guide book by UNESC for ASIA and the Pacific , Book No: ST/ESCAP/2026, UNESCAP, Bangkok

8. IEEE Bronze Book, Recommended Practice for Energy Conservation and cost effective planning in Industrial facilities., IEEE Inc, USA.
9. ASHRAE Handbooks, 1997-2000, American Society of Heating, Refrigerating and Air-conditioning Engineers Inc., Atlanta, GA.
10. Richard E. Putman, *Industrial energy systems: analysis, optimization, and control*, ASME Press, 2004

EE6101D SYSTEMS THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Integrate the concepts of linear algebra to be applied in systems theory
CO2: Explain the various tools used for the analysis of both LTI and LTV systems
CO3: Apply various techniques for the analysis of system stability
CO4: Analyze and categorize systems with respect to various properties

Module 1: (8 hours)

Basics of linear algebra - Vector spaces, dimension, basis, subspaces, dual spaces, annihilators, direct sum, linear transformations, matrix representations, similarity, rank and nullity.

Module 2: (9 hours)

Linear Systems –State space models, explicit solutions to linear differential equations, solution to LTI and LTV systems, Solutions to homogeneous and non homogeneous cases, Computation of matrix exponentials using Laplace transforms and Jordan Normal form, positive definite matrices, quadratic forms.

Module 3: (10 hours)

Minimal realizations and co-prime fractions, canonical forms,Markovparameters,Hankelmatrices

Stability - Internal or Lyapunov stability, Lyapunov stability theorem, Eigen value conditions for Lyapunovstability,Input -Output stability: BIBOstability, Time domain conditions for BIBO stability. Frequency domain conditions for BIBOstability. BIBO versus Lyapunov stability

Module 4: (12 hours)

Controllability and Observability - Controllable and reachable subspaces, Physical examples and system interconnections, Reachability and controllability Gramians, Controllabilty matrix(LTI), Eigen vector test for controllability, Lyapunov test for controllability, Controllable decomposition and block diagram interpretation, Stabilizable system, Eigen vector test for stabilizability, Popov-Belevitch_Hautus (PBH) Test for stabilizability, Lyapunov test for stabilizability. Feedback stabilization based on Lyapunov test, Unobservable and unconstructable subspaces, Physical examples, observability and Constructability Gramians, Gramian based reconstruction, Duality (LTI), Observable decompositions, Kalman decomposition theorem, Detectability, detectability tests, State estimation, Eigen value assignment by output injection, Stabilization through output feedback

References:

1. Chi-Tsong Chen, *‘Linear System Theory and Design’,* Oxford University Press,1984
2. John S. Bay, *‘Fundamentals of Linear State Space Systems’,* Mc-Graw Hill, 1999
3. Thomas Kailath, *‘Linear System’,* Prentice Hall, 1990
4. Gillette, *‘Computer Oriented Operation Research’*, Mc-Graw Hill Publications.
5. K. Hoffman and R. Kunze, *‘Linear Algebra’*, Prentice-Hall (India), 1986.
6. F.M. Callier and C.A. Desoer, *‘Linear System Theory’*, Springer Verlag, 1991
7. P. Halmos, *‘Finite Dimensional Vector Spaces’*, Springer, 1984

EE6102D OPTIMAL AND ROBUST CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply the various concepts in the mathematical area of 'calculus of variation' for solving optimal control problems.

CO2: Develop methods of problem formulation pertaining to optimal control and design of optimal controllers

CO3: Analyse robustness of systems and develop skills useful in controlling systems when accurate mathematical models are unavailable

CO4: Design and synthesis robust controllers for practical systems

Module 1: (10 hours)

Calculus of variations: Examples of variational problems, Basic calculus of variations problem, Weak and strong extrema, Variable end point problems, Hamiltonian formalism and mechanics: Hamilton's canonical equations.

From Calculus of variations to Optimal control :Necessary conditions for strong extrema, Calculus of variations versus optimal control, optimal control problem formulation and assumptions, Variational approach to the fixed time, free end point problem.

The Pontryagin's Minimum principle: Statement of Minimum principle for basic fixed endpoint and variable end point control problems, Proof of the minimum principle, Properties of the Hamiltonian, Time optimal control problems. Minimum energy problems.

Module 2: (10 hours)

Linear Quadratic Regulator: Finite horizon LQR problem-Candidate optimal feedback law, Ricatti differential equations (RDE), Global existence of solution for the RDE. Infinite horizon LQR problem-Existence and properties of the limit, solution, closed loop stability.LQR using output feedback: Output feedback LQR design equations, Closed loop stability, Solution of design equations .Numerical solution of Riccatti Equations-Linear Quadratic tracking control: Tracking a reference input with compensators of known structure, Tracking by regulator redesign, Command generator tracker, Explicit model following design. Linear Quadratic Guassian controller (LQG) and Kalman-Bucy Filter: LQG control equations, estimator in feedback loop, steady state filter gain, constraints and minimizing control, state estimation using Kalman-Bucy Filter, constraints and optimal control.

Module 3: (10 hours)

Robust Control - Control system representations, System stabilities, Co-prime factorization and stabilizing controllers, Signals and system norms, Modelling of uncertain systems - Unstructured Uncertainties-Additive, multiplicative and other forms. Parametric uncertainty, Interval Systems, Structured uncertainties, Linear fractional transformation Robust design specifications: Small gain theorem and robust stabilization, Performance considerations, Structured singular values. Design - Mixed sensitivity optimization, 2-Degree of freedom design, Sub-optimal solutions, H_2 /H_∞ Systems.

Module 4: (9 hours)

Loop-shaping design procedures: Robust stabilization against Normalized co-prime factor perturbation, Loop shaping design procedures, μ - Analysis and Synthesis - Consideration of robust performance, μ-synthesis: D – K iteration method, Schur Compliment & Linear Matrix Inequalities: Some standard LMI problems – eigen - value problems, generalized eigen - value problems; Algorithms to solve LMI problems – Ellipsoid algorithm, interior point methods.

References:

1. D. W.Gu, P. Hr.Petkov and M.M.Konstantinov, '*Robust Control esign with MATLAB'*, Springer, 2005.
2. Alok Sinha, *'Linear Systems-Optimal and Robust Controls',* CRC Press, 2007.
3. S. Skogestad and Ian Postlethwaite, *'Multivariable feedback control'*, John Wiley & Sons, Ltd, 2005.
4. G.E. Dullerud, F. Paganini, *'A course in Robust control theory-A convex approach'*, Springer, 2000.
5. Kemin Zhou with J.C. Doyle and K. Glover, *'Robust and Optimal control,'* Prentice Hall, 1996.
6. Kemin Zhou, John Comstock Doyle, Keith Glover, *'Robust and optimal control,'* PrenticeHall,1996.
7. Kemin Zhou, John Comstock Doyle, *Essentials of robust control*, Prentice Hall, 1998.
8. Stephen Boyd, Laurent El Ghaoul, Eric Feron, '*Linear Matrix Inequalities in System and ControlTheory',* SIAM, 1994.

EE6103D MEASUREMENTS AND INSTRUMENTATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Recognize about general units errors and significant digits in measurements.
CO2: Discuss about analog instruments and null balance methods for measurements.
CO3: Discuss digital measurement techniques.
CO4: Outline the applications of Data Acquisition Systems and virtual instrumentation.

Module 1: (8 Hours) Units, significant digits and errors in measurements

C.G.S electrostatic and electromagnetic systems of units- Practical and legal units and their relationship to the absolute units- Dimensions of electrical quantities- The M.K.S. system of units- International and absolute units and standards, significant digits.
Measurement and Error-Accuracy and precision- Types of errors- Systematic and random errors, propagation of errors.

Module 2: (13 hours) Analog instruments and null balance methods for measurements

Analog Indicating instruments- Moving iron instruments- Moving coil instruments- Permanent magnet and dynamometer type instruments- electrostatic instruments- thermal instruments- induction instruments- rectifier instruments
Null balance methods of measurement-potentiometer Principles-Bridge configuration-AC Bridges-Classification of AC bridge circuits- DC bridge analysis- Extension of instrument range-current transformer theory- voltage transformers.

Module 3: (11 hours) Digital Measurement techniques

Digital Measurement techniques- counters and timers. Time measurement- phase measurement-capacitance measurement- frequency measurement- ratio of two frequencies- high frequency- low frequency- peak frequency-Voltage measurement using digital techniques- ADC's Digital Multimeter.
Graphical measurement techniques- CRO-DSO

Module 4: (7 hours) Data acquisition systems and virtual instrumentation

Analog and digital data acquisition systems-Virtual instrumentation- concepts- virtual versus real instrumentation - physical quantities and analog interfaces, hardware and software- user interfaces-applications of virtual instrumentation.

References:

1. A.D. Helfrick, W.D. Cooper,'*Modern Electronic Instrumentation and Measurement Techniques'*, Prentice-Hall of India pvt ltd, 1994.
2. Golding and Widdis, *'Electrical measurements and measuring instruments'*,Reem publications, Newdelhi, 5thEdn, 2009
3. Ernest Frank,*'Electrical measurement analysis'*, Tata McGraw-hill publishing company ltd, Bombay,1959
4. G.W. Johnson, *'LabVIEW graphical programming practical application in Instrumentation and Control'*, McGraw Hill, New York, 1997.

EE6104D ADVANCED INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Summarize about the fundamental concepts of measurement systems.
CO2: Recognise the static and dynamic characteristics of measuring instruments.
CO3: Review the mathematical modelling and time response of first order and second order measurement systems.
CO4: Study and analysis of amplitude modulation of measurements and the design consideration of such amplitude modulated measurement systems.
CO5: Discuss the response of measurement systems to random inputs.
CO6: Outline the requirements to ensure accurate measurements.

Module 1: Generalized measuring system (9 hours)

Generalized input output configuration of measuring system. Different methods of correction, General principles. Methods of inherent sensitivity, principle of filtering, method of opposing inputs.

Module 2: Static and dynamic characteristics of measurement system (10 hours)

Static characteristics of measurement system. Computer aided calibration and measurement.Concept of development of software.Dynamic characteristics.Mathematical Models.Generalconcepts of transfer functions (with special reference to measuring system). Classification ofinstruments based on their order and their dynamic response and frequency response studies.

Module 3: Time domain analysis (10 hours)

Time Response of general form of first order and second order measurement systems to various input (a) periodic (b) transient.Characteristics of random signals.Measurement system response to random inputs.

Module 4: Signal Processing and Conditioning (10 hours)

Study and analysis of amplitude modulation of measurements and design consideration of suchamplitudes modulated measurement systems. Requirements on instrument transfer function toensure accurate measurements.

References:
1. Ernest O. Doebelin,' *Measurement system Application and Design'*, McGraw Hill International Editions, 1990
2. K. B. Klaasen, *'Electronic Measurement and Instrumentation'*, Cambridge University Press, 1996.
3. Bernard Oliver, John Cage, '*Electronic Measurements and Instrumentation'*, Tata McGraw-Hill Edition, 2008
4. A.D. Helfrick, W.D. Cooper,*'Modern Electronic Instrumentation and Measurement Techniques'*, Prentice-Hall of India pvt ltd, 1994

EE6105D DIGITAL CONTROL: THEORY AND DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Develop mathematical models of Digital Control Systems
CO2: Design and analyse digital control systems using classical techniques
CO3: Design and analyse SISO and MIMO digital control systems in the state space domain
CO4: Apply various techniques for the stability analysis of nonlinear digital control systems

Module 1: Introduction to digital control (9 hours)

Introduction -Discrete time system representation –Sample & Hold-Mathematical modeling of sampling process – Data reconstruction-Design of the hardware and software architecture - Software requirements-Selection of ADC and DAC- Choice of the sampling period –Prefilter/Antialiasing filters -Effects of quantization errors - Phase delay introduced by the ZOH-Sampling period switching- Dual-rate control
Modeling discrete-time systems by pulse transfer function -Revisiting Z-transform -Mapping of s-plane to z-plane -Pulse transfer function - Pulse transfer function of closed loop system - Sampled signal flow graph -Stability analysis of discrete time systems -Jury stability test - Stability analysis using bi-linear transformation

Module 2: Design of sampled data control systems (10 hours)

Design of PID controller-Filtering the derivative action- Integrator windup- Bumpless transfer between manual and automatic mode - Incremental form-Root locus method - Controller design using root locus - Root locus based controller design using MATLAB - Nyquist stability criteria - Bode plot - Lead compensator design using Bode plot - Lag compensator design using Bode plot - Lag-lead compensator design in frequency domain-Deadbeat response design -Design of digital control systems with deadbeat response - Practical issues with deadbeat response design - Sampled data control systems with deadbeat response

Module 3: Discrete state space model and state feedback design (9 hours)

Introduction to state variable model for SISO systems- Various canonical forms - Characteristic equation, state transition matrix - Solution to discrete state equation-Controllability, observability and stability of discrete state space models -Controllability and observability - Stability
Pole placement by state feedback - Set point tracking controller - Full order observer - Reduced order observer-Servo Design- State feedback with Integral Control-Deadbeat Control by state feedback and deadbeat observers -Output feedback design - Output feedback design: Theory - Output feedback design:Examples. Introduction to Multivariable & Multi-input Multi-output (MIMO) Digital Control Systems

Module 4: Nonlinear Digital control systems (11 hours)

Discretization of nonlinear systems - Extended linearization by input redefinition - - input and state redefinition - output differentiation - Extended linearization using matching conditions - Nonlinear difference equations - Logarithmic transformation- Equilibrium of nonlinear discrete-time systems - Lyapunov stability theory- Lyapunov functions - Stability theorems -Rate of convergence - Lyapunov stability of linear systems - Lyapunov's linearization method- Instability theorems - Estimation of the domain of attraction - Stability of analog systems with digital control-Hybrid Systems - State plane analysis - Discrete-tim.nonlinear controller design- Controller design using extended linearization- Controller design based on Lyapunov stability theory - Input-output stability and the small gain theorem- Absolute stability

References:

1. B.C Kuo , '*Digital Control Systems'* (second Edition),Oxford University Press, Inc., New York, 1992
2. G.F. Franklin, J.D. Powell, and M.L. Workman, '*Digital control of Dynamic Systems'*, Addison-Wesley Longman, Inc., Menlo Park, CA , 1998.
3. M. Gopal, '*Digital Control and State Variable Methods'*, Tata McGraw Hill Publishing Company, Third Edition, 2009.
4. John F. Walkerly, '*Microcomputer architecture and Programs'*, John Wiley and Sons Inc., New York, 1981.
5. K. Ogata, '*Discrete Time Control Systems'*, Addison-Wesley Longman Pte. Ltd., Indian Branch ,Delhi, 1995.
6. C. H. Houpis and G.B. Lamont, '*Digital Control Systems'*, McGraw Hill Book Company, 1985.
7. C.L.Philips and H.T Nagle,Jr., '*Digital Control System Analysis and Design'*, Prentice Hall, Inc., Englewood Cliffs,N.J.,1984
8. M. Sami Fadali Antonio Visioli, '*Digital Control Engineering Analysis and Design'*, Academic Press,225 Wyman Street, Waltham, MA 02451, USA,Second Edition.

EE6106D STOCHASTIC MODELING AND IDENTIFICATION OF DYNAMICAL SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the advanced topics of statistics and stochastic processes
CO1: Explain the stochastic modelling of uncertain signals and dynamical systems
CO3: Apply stochastic modelling for control system analysis and design
CO4: Choose suitable methods for control system identification
CO5: Develop algorithms for analytical modelling & optimal control

Module 1: Random variables & Stochastic processes (9 hours)

Probability spaces, random variables and probability distributions, expectations, transforms and generating functions, convergence. Gaussian, Exponential, Poisson, Weibull, Cauchy, Laplace distributions, Time series models, AR, MA ARMA, ARMAX, Markov process. Non-parametric and parametric methods for modelling.Fuzzy and probability.

Module 2: Stochastic process and development of system models(10 hours)

Elements of the theory of stochastic processes, Gauss Markov sequence model, Gauss Markov Process model-Discrete and Continuous-time Markov Chains (MCs): Transition probability matrix, Chapman-Kolmogorov equations; n-step transition and limiting probabilities, ergodicity, stationarity, correlation-random walk Brownian motion: Wiener process as a limit of random walk, White noise- PRBS-optimal smoothing, filtering and prediction for continuous and discrete linear systems.

Module 3: Bayesian estimation and System identification (10 hours)

Maximum likelihood estimation, linear mean square estimation- Parameter estimation for Time series models, AR, MA ARMA, ARMAX-efficiency and bias of estimators- minimizing prediction errors-Instrumental variable method-consistency and identifiability-Recursive methods- Matrix inversion lemma-RLS Algorithm-Weighted RLS algorithm- -Modelling with orthogonal functions and transforms -feature extraction-introduction to big data analytics- system identification experiments- design of inputs for system identification-persistent excitation-open loop and closed loop system identification.

Module 4: System Identification &Kalman Filter (10 hours)

Wiener Filter- estimation problem-Wiener Hopf equation- realizability- stochastic state estimation problem-optimal filtering and prediction-derivation of Kalman filter-Extended Kalman Filter-Unscented Kalman Filter-Combined state and parameter estimation-System identification for control.

References:

1. Schoukens, Johan,RikPintelon,YvesRolain,*“Mastering System Identification in 100 Exercises”*, Wiley IEEE Press, 2012
2. LingfengWang,Kay Chen Tan, *“Modern Industrial Automation Software Design”* , Wiley IEEE Press, 2012
3. Ravindra V. Jategaonkar, *“Flight Vehicle System Identification: A Time-Domain Methodology”,* Second Edition, Aerospace Research Central, American Institute of Aeronautics & Astronautics, USA, 2015.
4. J S Meditch, *“Stochastic Optimal Linear Estimation and Control*”, McGraw Hill Book Company, 1969
5. Charles K Chui, Guanrong Chen, “*Kalman Filtering with Real time Applications*”, Springer, 2009.

EE6108D NON LINEAR SYSTEMS AND CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse nonlinear systems using classical techniques
CO2: Analyse stability of non linear systems using advanced techniques
CO3: Analyse nonlinear feedback systems using time and frequency domain techniques
CO4: Design controllers for nonlinear systems using advanced methods

Module 1: Introduction and classical techniques (10 hours)

Characteristics of nonlinear systems – examples of systems exhibiting nonlinear phenomena- second order nonlinear autonomous systems- vector field representation- classification of equilibrium points – qualitative behavior near equilibrium points- limit cycles – existence of periodic orbits- Poincare-Bendixon criterion- Poincare index of equilibrium points- stability of periodic solutions- analysis of systems with piecewise constant inputs using phase plane analysis-Jump response.

Module 2: Lyapunov Stabilty (10 hours)

Existence and uniqueness of solutions of nonlinear state equations- stability of nonlinear systems - Lyapunov stability - local linearization and stability in the small – Centre manifold theorem- Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems- Variable gradient method- La Salle’s Invariance theorem – Input to state stability - L stability - L stability of state models-Small gain theorem- Passivity- Positive real transfer functions-L_2 and Lyapunov stability-Passivity theorems- Loop transformation.

Module 3: Time domain analysis of feedback systems and perturbation techniques (7 hours)

Absolute stability of feedback interconnections of a linear part and nonlinear part- Circle criterion- Popov criterion- Frequency theorem- Harmonic linearization- filter hypothesis- Describing function of standard nonlinearities- amplitude and frequency of limit cycle using SIDF.Pertubation techniques- Regular perturbation- Singular perturbation-Reduced model- boundary- layer model- Tikhonov’s theorem- slow and fast manifolds.

Module 4: Nonlinear system design tools (12 hours)

Control problems- stabilization via linearization - integral control via linearization- Gain scheduling- Feedback linearization-stabilization and tracking via state feedback control. Sliding mode control- Regulation via integral control- Lyapunov redesign- stabilization and nonlinear damping-Backstepping- Passivity based control- High gain observers. Linear Quadratic Regulators/Linear Quadratic Guassian Regulators-Numerical Solution for Riccatti Equations.
References:

1. Hassan K Khalil, *‘Nonlinear Systems’*, Prentice - Hall International (UK) 1996
2. Slotine& W.LI, *‘Applied Nonlinear Control’*, Prentice Hall, EngelwoodNewJersey 1991
3. AIsidori, *‘Nonlinear Control systems’* Springer verlag New york 1995
4. S. Wiggins, *‘Introduction to Applied Nonlinear Dynamical Systems and chaos’*, Springer Verlag New York 1990

5. H. Nijmeijer& A.J. Van Der schaft, *'Nonlinear Dynamic control Systems'*, Springer Verlag Berlin 1990.
6. Arther E Gelb & Vender Velde, *'Multiple input Describing function and Nonlinear System Design'*, MC Graw Hill 1968
7. Z Vukic, L Kuljaca, *'Nonlinear Control Systems',* Marcel Dekker, Inc., Newyork.

EE6121D DATA ACQUISITION & SIGNAL CONDITIONING

Pre-requisite:Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes:
CO1: Explain characteristics of transducers and various signal conditioning techniques.
CO2: Design filters for signal conditioning.
CO3: Explain signal conversion (analog to digital and digital to analog) as well as transmission techniques
CO4: Describe various interfacing techniques and standards for communication between instruments.

Module 1: Transducers & Signal Conditioning (10 hours)

Data Acquisition Systems (DAS)- Introduction . Objectives of DAS. Block Diagram Description of DAS- General configurations - Single and multichannel DAS-Transducers for the measurement of motion, force, pressure, flow, level, dc and ac voltages and currents (CTs, PTs for supply frequency as well as high frequency, Hall Effect Current Sensors, High Voltage Sensors , Opto-sensors, Rogowski Coil, Ampflex Sensors etc.) - Signal Conditioning: Requirements - Instrumentation amplifiers: Basic characteristics . Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Transmitters .Optical Fiber Based Signal Transmission- Piezoelectric Couplers- Intelligent transmitters.

Module 2: Filtering and Sampling (10 hours)

Review of Nyquist.s Sampling Theorem- Aliasing. Need for Prefiltering-First and second order filters - classification and types of filters - Low -pass, High-pass, Band-pass and Band-rejection and All Pass: Butterworth, Bessel, Chebyshev and Elliptic filters. Op-amp RC Circuits for Second Order Sections-Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers

Module 3: Signal Conversion and Transmission (10 hours)

Analog-to-Digital Converters(ADC) -Multiplexers and demultiplexers - Digital multiplexer . A/D Conversion . Conversion Processes , Speed, Quantization Errors . Successive Approximation ADC . Dual Slope ADC . Flash ADC . Digital-to-Analog Conversion (DAC) . Techniques, Speed, Conversion Errors, Post Filtering-Weighted Resistor, R-2R, Weighted Current type of DACs- Multiplying Type DAC-Bipolar DACs- Data transmission systems-Schmitt Trigger-Pulse code formats- Modulation techniques and systems-Telemetry systems.

Module 4: Digital Signal Transmission And Interfacing (9 hours)

DAS Boards- Introduction. Study of a representative DAS Board-Interfacing Issues with DAS Boards, I/O vs Memory Addressing, Software Drivers, Virtual Instruments, Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - RS-232C-USB-4-to-20mA current loop serial communication systems.Communication via parallel port . Interrupt-based Data Acquisition.Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques- Limitations of Polling . Circular Queues

References:

1. Ernest O Doeblin., *'Measurement Systems: Application and Design',* McGraw Hill (Int. edition) 1990

2. George C.Barney, *‘Intelligent Instrumentation’*, Prentice Hall of India Pvt Ltd., New Delhi, 1988.
3. Ibrahim, K.E., *‘Instruments and Automatic Test Equipment*’, Longman Scientific & Technical Group Ltd., UK, 1988.
4. John Uffrenbeck, *‘The 80x86 Family ,Design, Programming, And Interfacing*’, Pearson Education , Asia, 2002
5. Bates Paul, *‘Practical digital and Data Communications with LSI*’, Prentice Hall of India, 1987.
6. G.B. Clayton, *‘Operational Amplifiers*’, Butterworth &Co, 1992
7. A.K Ray, *‘Advanced Microprocessors and Peripherals*’, Tata McGrawHill, 1991
8. Oliver Cage, *‘Electronic Measurements and Instrumentation’.*, McGraw-Hill, (Int. edition) 1975

EE6122D BIOMEDICAL INSTRUMENTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course outcomes

CO1: State and recognize the practical problems faced in objective analyses of biomedical signals.
CO2: Describe and interpret the various mathematical techniques involved in biomedical signal processing
CO3: Illustrate and examine the characteristics of signals like EEG and apply the signal processing techniques to obtain the medically significant information from the signals concerned.
CO4: Analyze and infer the entities associated with bio-signals.
CO5: Evaluate and conclude the medically significant information obtained from the task of biomedical signal processing.

Module1: (10hours)

Fundamentals of medical instrumentation – physiological systems of body –regulation of medical devices– origin of bio potentials – Sodium –Potassium pump –Goldman Hodgkin – Katz equation – biomedicaltransducers – electrode-electrolyte interface – half cell potential – ECG – 12 lead systems – heart rate variability – cardiac pacemakers – defibrillators - EMG – EEG

Module 2: (10 hours)

Measurement of cardiac output – indicator dilution method – ultrasonic blood flow meter –electromagnetic blood flow meter – blood pressure measurement – oximetry – ear oximeter – pulseoximeter –skin reflectance oximeter -measurement on pulmonary system – spirometry –pulmonaryfunction analyzers – ventilators

Module 3: (9 hours)

Lasers in medicine – Argon laser – Carbon dioxide laser -laser safety –X ray applications –X-ray machine– dental X-ray machine – ultrasound in medicine –electro therapy – hemodialysis –artificial kidney –dialyzers –membranes for hemodialysis.

Module 4: (10 hours)

Measurement of pH, pCO_2, pO_2 - radiotherapy– audiometry - electrical safety in hospitals.

Introduction to Biomedical signals, Characteristics of bio medical signals, bio signal acquisition, Artifacts, Fourier transform and Time-frequency analysis of biomedical signals.

References:

1. Geddes & Baker, "*Principles of applied biomedical instrumentation*" Wiley Inter science, 3rd edition,1975
2. R S Khandpur, *"Hand book of biomedical instrumentation*", TMH,4th edition, 1987
3. Cromwell Leslie, *"Biomedical instrumentation and measurements"*, PHI, 1980
4. Brown Carr, *"Introduction to Biomedical equipment technology"*, Prentice Hall, 1981
5. John Enderle, *"Introduction to Biomedical Engineering"*, Academic Press, 2005
6. Joseph D Bronzino, *"Biomedical engineering hand book"*, CRC Press, 2000
7. MetinAkay (editor), *"Wiley encyclopedia of biomedical Engineering*", Wiley, 2003
8. E.N.Bruce, *"Biomedical Signal Processing & Signal Modeling*", Wiley, 2001

9. L.Sörnmo, P Laguna, *“Bioelectrical Signal Processing in Cardiac & Neurological Applications”,* Elsevier, 2005.
10. R.M.Rangayyan, *“Biomedical Signal Analysis:A case study approach*”, IEEE Press and Wiley 2002.
11. Semmlow, Marcel Dekker*, “Biosignal and Biomedical Image Processing*”, 2004
12. Enderle, *“Introduction to Biomedical Engineering”*, 2/e, Elsevier, 2005
13. D.C.Reddy , *“Biomedical Signal Processing: Principles and techniques*”, Tata McGraw Hill, New Delhi, 2005
14. A. Cohen, *“Biomedical Signal Processing”,* Vol. I and II, CRC, Boca Raton, FL, 1986
15. W. J. Tompkins (Editor), “*Biomedical Digital Signal Processing*”, Prentice Hall, 1995
16. S. R. Devasahayam, “*Signals and Systems in Biomedical Engineering: Signal Processing and Physiological Systems Modeling”*, Kluwer Academic/ Plenum, New York, NY, 2000

EE6125D ADAPTIVE CONTROL THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Integrate the concepts of norms and spaces to be applied in adaptive control theory
CO2: Apply identification techniques for design of adaptive controller
CO3: Explain direct and indirect adaptive control techniques
CO4: Describe advanced adaptive control methods along with case studies and computer simulations

Module 1 : Preliminaries (10 Hours)

Norms and Lp spaces-positive definite matrices-input –output stability-Lp stability-small gain theorem-Positive real functions and stability-Analysis of Dynamical Systems ,Analysis of Solutions to Differential Equations., Equilibria and Stability. Invariant Sets. Lyapunov Stability Theory and Performance Analysis.,Nonautonomous Systems., LaSalle Extensions, Barbalat Lemma. Basic approaches to adaptive control -Applications of adaptive control. Introduction to types of Adaptive Control-Model Reference-Variable Structure-Sliding Mode- Neuro-Fuzzy-Learning Control-Intelligent Control using schematic diagrams and literature survey.

Module 2: Identification (10 hours)

Identification problem- Identification of linear time-invariant systems.Adaptive observers.Sufficient richness condition for parameter convergence. Equation error and output error methodsGradient *and* least-squaresalgorithms: Linear error equation. Gradient and normalized gradient algorithms. Least-squares algorithms (batch, recursive, recursive with forgetting factor). Convergence properties.Identification for Control.
Frequency-domain analysis and averaging approximations: Averaging of signals. Averaging theory for one-time scale and two-time scale systems.Applications to adaptive systems.

Module 3: Model Reference Adaptive Control (10 hours)

Indirect adaptive control: Pole placement adaptive control. Model reference adaptive control.Predictive control.Singularity regions and methods to avoid them.
Direct adaptive control: Filtered linear error equation. Gradient and pseudo-gradient algorithms.Strictly positive real transfer functions and Kalman-Yacubovitch-Popov lemma.Lyapunov redesign.Passivity theory. Direct model reference adaptive control. One case study of MRAC and computer based design.

Module 4: Methods in Adaptive Control (9 hours)

Adaptive Backstepping.,Adaptive Output Feedback Control, Adaptive NeuroControl., Examples of Adaptive Control.One case study and computer simulation.

References:

1. K.J. Astrom and B. Wittenmark, '*Adaptive Control',* Addison-Wesley, 2nd edition, 1995.
2. P.A. Ioannou& J. Sun, '*Robust Adaptive Control'*, Prentice Hall, Upper Saddle River, NJ, 1996..
3. I.D. Landau, R. Lozano, and M. M'Saad, '*Adaptive Control'*, Springer Verlag, London, 1998.
4. K.S. Narendra and A.M. Annaswamy, '*Stable Adaptive Systems'*, Prentice-Hall, 1989.
5. S. Sastry and M. Bodson*, 'Adaptive Control: Stability, Convergence, and Robustness'*, Prentice-Hall, 1989.

EE6134D NETWORKED CONTROL AND MULTI AGENT SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Integrate the basic concepts to formulate networked control problems
CO2: Describe various decentralized control strategies for networked control systems
CO3: Develop various control strategies for multi-agent robotics
CO4: Develop models and strategies for mobile sensor and communication networks

Module 1: Basic concepts in networked control (8 Hours)

Review of Graph Theory-Connected Graph-Incidence Matrix-Tree-cutset-loop/cycles-Minimum Spanning Tree-Network Models -graphs, random graphs, random geometric graphs, state-dependent graphs-Networked control systems-Proximity graphs - Algebraic and spectral graph theory - Connectivity: Cheeger's inequality -switching networks- From biological swarms to graph-based models-Rendezvous: A canonical problem

Module 2: Decentralized Control (10 hours)

The agreement protocol: static case- Reaching decentralized agreements- Consensus equation: Static case- Leader networks and distributed estimation- Discrete time consensus.
The agreement protocol: dynamic case: Switched networks- Lyapunov-based stability- Consensus equation: Dynamic case-Biological models: Flocking and swarming- Alignment and Kuramoto's coupled oscillators.
Distributed estimation -Computational, communications, and controls resources in networked control systems-Distributed control- Convex Optimization -Optimization-based control design.

Module 3: Multi Agent Robotics (11 hours)

Formations - Graph rigidity -Persistence -Formation control, sensor and actuation models-distance based formations, rigidity, position based formations, formation infeasibility -Consensus problem- static, dynamic, distributed estimation, leader-follower architectures for consensus-Reaching decentralized agreements through cooperative control- leader-follower networks-Network controllability- Network feedback-Averaging Systems-Positive Systems- nonholonomic, double integrator, rigid body dynamics-Collision avoidance: potential fields, navigation functions. Introduction to artificial intelligence & deep learning for multi-agent robotics.

Module 4: Mobile sensor and communication networks (10 hours)

Sensor networks: Coverage control- Coverage and detection problems-Gabriel and Voronoi graphs-voronoi-based cooperation strategies-Random graphs - LANdroids: Communication networks - Communication models- mobile communications networks- connectivity, connectivity maintainance, sampling, delays, packet losses, quantization, security -Swarming-sensor networks: sensing constraints, aggregation, dispersion, coverage control, deployment, flocking. Internet of things(IOT)

References:

1. Mehran Mesbahi and Magnus Egerstedt, '*Graph Theoretic Methods in Multiagent Networks*,' Princeton University Press, 2010.

2. F. Bullo, J. Cortes, and S. Martinez, '*Distributed Control of Robotic Networks'*, Princeton, 2009.
3. C. Godsil and G. Royle, '*Algebraic Graph Theory'*, Springer, 2001.
4. P. J. Antsaklis and P. Tabuada,, '*Networked Embedded Sensing and Control',* Springer 2006.
5. C. Godsil and G. Royle, *'Algebraic Graph Theory'*, Springer, 2001.
6. M. Mesbahi and M. Egerstedt,*'Graph Theoretic Methods in Multi-Agent Networks'*, Princeton University Press, 2010.
7. Wei Ren, Randal W. Beard, *'Distributed Consensus in Multi-vehicle Cooperative Control'*, Communications and Control Engineering Series, Springer-Verlag, London, 2008

EE6136D GUIDANCE, NAVIGATION AND CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain the theory related to navigation
CO2: Describe the various aspects in advanced navigation system
CO3: Articulate the theory related to navigation and guidance
CO4: Develop formulation of optimal control for performance of aerospace systems

Module 1: (10 hours)

Fundamentals of Navigation - geometric concepts of navigation- reference frames- Euler angles-direction cosine matrix- quaternion representation- coordinate transformations- comparison of transformation methods. Inertial navigation- inertial platforms- stabilized platforms – gimballed and strapdown INS – IMU Navigation equations- Schuler principle and mechanization

Module 2: (10Hours)

Inertial sensors, gyros- principle of operation- TDF and SDF gyros- precession- Nutation-gimbal lock-gimbal flip- gyro transfer function- rate gyro- integrating gyro- DTG – ring laser gyro- performance parameters. Accelerometers- transfer function- performance parameters.
Integrated navigation-externally aided navigation- introduction to radars- radar equations- operation – types of radar
Basics of satellite navigation- GPS and GNSS- principles of advanced navigation system.

Module 3: (10 Hours)

Fundamentals of aerodynamics- airfoils -aerodynamic forces moments and coefficients- control surfaces-anatomy of aerospace vehicles- Equation of motion.Classification of missiles- Fundamentals of GuidanceTaxonomy of guidance laws- Command and Homing Guidance- Classical Guidance laws.Modern guidance Laws- Guidance Laws derived from optimal control Theory and Lyapunov method. Missile autopilots- FCS- Control surfaces

Module 4: (9 Hours)

Launch Vehicle Guidance- implicit and explicit guidance- open loop and closed loop guidance- FE guidance-E guidance – VG guidance – Q guidance -Delta guidance
Formulation of optimal control for performance of aerospace systems- Riccatti equation – performance measure- optimal mid course Guidance

References:

1. Anthony Lawrence, *"Modern Inertial Technology*", Second Edition. SpringerVerlag, New York, Inc., 2001.
2. David Titteron and John Weston, "*Strapdown Inertial Navigation Technology*" Second Edition IEE Radar, Sonar, Navigation and Avionics Series, 2005.
3. Ching-Fang Lin, "*Modern Navigation, Guidance and Control Processing*", Prentice-Hall Inc., Engle Wood Cliffs, New Jersey, 1991
4. George M. Siouris, "*Missile Guidance and Control Systems*", Springer Verlag , New York Inc., 2004.
5. Paul Zarchan , "*Tactical and Strategic Missile Guidance*", AIAA, Inc., Sixth Edition, 2012.

6. N.A. Shneydor, "*Missile Guidance and Pursuit: Kinematics, Dynamics and Control*", Ellis Horwood Publishers, 1998.
8. Robert C. Nelson, *"Flight Stability and Automatic Control*", WCB McGraw-Hill, 2/e, 1998.
7.Roger R. Bate, "*Fundamentals of Astrodynamics*", Dover Publications Inc., New York, 1971.
9. Edward V. B. Stearns, "*Navigation and Guidance in Space*", Prentice-Hall Inc., Englewood Cliffs, New Jersey.

EE6140D ADVANCED SOFT COMPUTING TECHNIQUES

Pre-requisite**:** Nil

L	T	P	C
3	0	0	3

Total hours: **39**

Course Outcomes:
CO1: Construct intelligent systems and control using Artificial neural network
CO2: Integrate theoretic foundations of Fuzzy Logic Systems to be used in engineering applications.
CO3: Describe the concepts of genetic algorithms
CO4: Apply the knowledge of Soft Computing Techniques in engineering problems
CO5: Simulate intelligent control systems to evaluate the performance

Module 1: (9 hours)

Introduction Neural Networks, Biological Neuron, Biological and Artificial Neuron Models, types of Neuron Activation function, ANN Architectures, supervised, and unsupervised learning, Perceptron Models, training Algorithms, Limitations of the Perceptron Model and Applications, Computer based simulation

Module 2: (11 hours)

Multilayer Feed forward Neural Networks - Back propagation Algorithm, Limitations of Back propagation Algorithm, Radial Basis Function network structure - covers theorem and the separability of patterns - RBF learning strategies, Applications in forecasting and pattern recognition and other engineering problems, Computer based simulation

Module 3: (11 hours)

Introduction to classical sets - properties, Operations and relations; Fuzzy sets, Membership, Uncertainty, Operations, properties, fuzzy relations, cardinalities, membership functions., Fuzzification, Membership value assignment, development of rule base and decision making system, Defuzzification to crisp sets, Defuzzification methods - Mamdani Fuzzy Models, Sugeno Fuzzy Models - engineering applications

Module 4 :(8 hours)
Introduction to Optimization, types of optimization problem, optimization algorithms, classification, History of evolutionary, Advantages of evolutionary computation, Introduction to genetic algorithms, The genetic computation process-natural evolution-parent selection-crossover-mutation-properties - classification - Application to engineering problems, Computer simulation practices.

References:

1. B.Yegnanarayana, *"Artificial Neural Networks,"* PHI, India, 2006.
2. Limin Fu, *"Neural Networks in Computer Intelligence,"* McGraw Hill, 2003.
3. N. Yadaiah and S. Bapi Raju, *"Neural and Fuzzy Systems: Foundation, Architectures and Applications,"* Pearson Education
4. Goldberg D.E., *"Genetic Algorithms in Search Optimization and Machine Learning",* Addison Wesley,1989

EE6201D COMPUTER METHODS IN POWER SYSTEM ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Formulate network admittance and impedance matrix for various analyses of power systems.
CO2: Execute load flow and short circuit analysis on large scale AC, DC and AC-DC power systems using digital techniques.
CO3: Conduct optimal scheduling and unit commitment of generators.
CO4: Execute state estimation and contingency analysis on large scale power systems using digital techniques.

Module 1: (10 hours)

Network modelling - System Graph. Loop, Cutest and Incidence Matrices - Y Bus Formation – Mutually coupled branches in Y Bus - solution techniques for linear networks -Guassian Elimination, LU Factorization, Network reduction techniques - Sparsity programming and Optimal Ordering - [ZBUS] Building Algorithm with Mutually coupled branches - digital simulation.

Module 2: (10 hours)

Power Flow Analysis: Newton-Raphson Method. Decoupled and Fast Decoupled Methods, DC Power Flow, AC-DC Load Flow Analysis, Load Flow under Power Electronic Control

Fault Analysis: Sequence Matrices. Symmetrical and Unsymmetrical Short-Circuit Analysis of Large Power Systems - Phase Shift in Sequence Quantities Due To Transformers - digital simulation

Module 3: (9 hours)

Power System Optimization - Unit Commitment - Priority List and Dynamic Programming Methods -

Optimal Load Flow Solution - Optimal scheduling of Hydrothermal System - Optimum Reactive Power Dispatch and control, Economic scheduling in deregulated environment - AI Applications - digital simulation

Module 4: (10 hours)

Power System Security, Factors Affecting Security. State Transition Diagram. Contingency Analysis Using Network Sensitivity Method And AC Power Flow Method, Z bus method, Correcting The Generation Dispatch Using Sensitivity Methods, State Estimation, Bad data detection, State estimation with phasor measurements.- digital simulation

References:

1. John J. Grainger and William D. Stevenson, *Power System Analysis*, Tata McGraw-Hill, 2003
2. Haadi A. Sadat, *Power System Analysis*, McGraw Hill Co. Ltd., India, 2000.
3. I.J. Nagarath, D.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.
4. George L. Kusic, *Computer Aided Power System Analysis*, Prentice Hall of India (P) Ltd., New Delhi, 1989.
5. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation and Control*, John Wiley & Sons, New York, 1984.

6. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer modelling of Electric Power Systems,* Wiley, New York, 1983.
7. A.K. Mahaianabis, D.P. Kothari, S.I. Ahson, *Computer Aided Power System Analysis & Control,* Tata McGraw Hill, New Delhi, 1988.
8. O.I. Elgard, *Electric Energy System Theory: An Introduction*, 2nd ed., McGraw Hill, New York, 1982.
9. Mariesa L. Crow, *Computational Methods for Electric Power Systems*, CRC Press, 2010.
10. T. J. E. Miller, *Reactive power control in Electrical system*, John Wiley & Sons, New York, 1982.
11. Arthur R. Bergen, Vijay Vittal, *Power Systems Analysis*, Pearson Education, 2009.

EE6204D FACTS AND CUSTOM POWER

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyze passive and active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.
CO2: Analyze operation and control of various FACTS devices.
CO3: Digital simulation and case study of various FACTS controllers.
CO4: Design and analyze Custom power devices for power quality improvement.

Module 1: (10 hours)

Power flow in Power Systems – Steady-state and dynamic problems in AC systems – Voltage regulation and reactive power flow control in Power Systems – control of dynamic power unbalances in Power System - Power flow control -Constraints of maximum transmission line loading - Benefits of FACTS Transmission line compensation- Uncompensated line -shunt compensation - Series compensation –Phase angle control.– reactive compensation at transmission and distribution level – Static versus passive VAr Compensators

Module 2: (10 hours)

Static shunt compensators: SVC and STATCOM - Operation and control of TSC, TCR and STATCOM - Compensator control - Comparison between SVC and STATCOM.

Static series compensation: GCSC, TSSC, TCSC, SSSC -Static voltage and phase angle regulators - TCVR and TCPAR - Operation and Control –Applications – Digital simulation and analysis - SSR and damping schemes

Module 3: (9 hours)

Unified Power Flow Controller: Circuit Arrangement, Operation and control of UPFC- Basic Principle of P and Q control- independent real and reactive power flow control- Applications - Interline power flow controller – Transient stability improvement and power oscillation damping -Digital simulation and analysis.

Module 4: (10 hours)

Power quality problems in distribution systems – Custom power devices - mitigation of harmonics, passive filters, active filtering – shunt, series and hybrid filters and their control – Distribution STATCOM, Dynamic Voltage Restorer – Unified Power Quality Conditioner - Digital simulation and analysis- Custom Power Devices for Isolation, Protection and Reconfiguration-STS, SCL,SCB.

References:

1. K R Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International Publishers, 2007.
2. X P Zhang, C Rehtanz, B Pal, *Flexible AC Transmission Systems- Modelling and Control*, Springer Verlag, Berlin, 2006.
3. N.G. Hingorani, L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press Book, Standard Publishers and Distributors, Delhi, 2001.
4. K.S.Sureshkumar , S.Ashok , *FACTS Controllers & Applications*, e-book ed., Nalanda Digital Library, NIT Calicut,2003.

5. G T Heydt , *Power Quality*, McGraw-Hill Professional, 2007.
6. T J E Miller, *Static Reactive Power Compensation*, John Wiley and Sons, Newyork, 1982.
7. F.P. Beer and E.R. Johnston, *Vector Mechanics for Engineers – Statics*, McGraw Hill Book Company, 2000.

EE6206D DIGITAL PROTECTION OF POWER SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes

CO1: Explain various digital protective schemes for transmission lines and power apparatus.
CO2: Select and design instrument transformers for a specific protection scheme design.
CO3: Realise numerical relays in hardware platform.
CO4: Conduct testing and coordination of relays.

Module 1: (8 hours)

Protective Relaying - Qualities of relaying - Definitions - Codes- Standards; Characteristic Functions; Classification – analog - digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection.

Module 2: (13 hours)

Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms-travelling wave protection schemes; Relay Schematics and Analysis- Over Current Relay-Instantaneous/Inverse Time –IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types Characteristics. Relay coordination- Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples

Module 3: (11 hours)

Digital Protection of power system apparatus – protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection. Bus bar protection - line protection - distance protection–long EHV line protection - Power line carrier protection Motors protection; Pilot wire and Carrier Current Schemes; Reactor protection – Protection of boosters - capacitors in an interconnected power system. System grounding – ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Re-closing and synchronizing.

Module 4: (7 hours)

Integrated and multifunction protection schemes -SCADA based protection systems- Fault Tree Analysis; Testing of Relays- Field test procedures for protective relays.

Adaptive relaying- AI & Fuzzy Based Protection, Intelligent Transmission Line Relaying Fault Detection

References:

1. A T John and A K Salman, *Digital protection for power systems-IEE power series-15*, Peter Peregrines Ltd,UK,1997
2. C.R. Mason, *The art and science of protective relaying*, John Wiley &sons, 2002
3. Donald Reimert, Protective relaying for power generation systems, Taylor & Francis-CRC press 2006
4. Gerhard Ziegler, *Numerical distance protection*, Siemens, 2nd ed, 2006

5. A.R.Warrington, *Protective Relays, Vol .1&2*, Chapman and Hall, 1973.
6. T S.Madhav Rao, *Power system protection static relays with microprocessor applications*, Tata McGraw Hill Publication, 1994
7. *Power System Protection Vol. I, II , III&IV*, The Institution Of Electrical Engineers, Electricity Association Services Ltd., 1995
8. Helmut Ungrad , Wilibald Winkler, Andrzej Wiszniewski*, Protection techniques in electrical energy systems*, Marcel Dekker, Inc. 1995
9. Badri Ram , D.N. Vishwakarma, *Power system protection and switch gear*, Tata McGraw Hill, 2001
10. Blackburn, J. Lewis, *Protective Relaying, Principles and Applications*, Marcel Dekker, Inc., 1986. Anderson, P.M, Power System Protection,. McGraw-Hill, 1999
11. Singh L.P ,*Digital Protection, Protective Relaying from Electromechanical to Microprocessor*, John Wiley & Sons, 1994
12. Wright, A. and Christopoulos, C*, Electrical Power System Protection*, Chapman & Hall, 1993,
13. Walter A. Elmore, J. L. Blackburn, *Protective Relaying Theory and Applications*, ABB T&D Co. Marcel Dekker, Inc. 2004
14. Arun G. Phadke, James S. Thorp, *Computer Relaying for Power Systems*, Marcel Dekker, Inc 2009
15. P M Anderson, *Power System Protection*, IEE Press, 2012
16. Edward Wilson Kimbark, *Power System Stability, Volume II: Power Circuit Breakers and Protective Relays,* Wiley-IEEE Press, March 1995.
17. IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems - Buff Book, IEEE Standard 242-198.

EE6203D DISTRIBUTED GENERATION & MICROGRID

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Analyze the concept of distributed generation and technologies
CO2: Investigate the technical challenges of Distributed Generation technologies
CO3: Design the microgrid architectures and its control operation
CO4: Explore smartgrid technologies and infrastructure

Module 1: (10 hours)

Modern Power System: Generation - Transmission - Distribution - Loads - Introduction to Distributed Generation (DG) - Technologies of DG - IEEE 1547- Solar photovoltaic generation - wind energy - Wind power plants - Microturbines - Fuel Cell - Storage Systems - batteries, fly-wheels, ultracapacitors - unit sizing of DGs - Case studies

Module 2: (10 hours)

Penetration of DGs Units in Power Systems - Integration of DGs Units in Distribution Network -Modern Power Electronics for DGs Applications – multiple and single input dc-dc converters - ac-dc and dc-ac converters - Technical restrictions - Protection of DGs - Economics of DGs –Pricing and Financing framework for DG units - Optimal placement of DGs - Case studies

Module 3: (10 hours)

Introduction to Microgrids - AC and DC microgrids - Operational Framework of Microgrids - anti-islanding schemes - Distribution Management System (DMS) - Microgrid System Central Controller (MGCC) - Local Controllers (LC) - Economic, environmental and operational benefits of Microgrids in a distribution network - Demand Response Management in Microgrids - Business Models and Pricing Mechanism in Microgrids - Interconnection of Microgrids

Module 4: (9 hours)

Introduction to Smart Grids (SG) - Factors affecting the growth of SG - The global reality in the field of smart grids and transition into future grids - Smart Agents - Electronics and communications infrastructure in SG - ICT Technologies - smart meters - metering infrastructures - metering equipment - communication of metering equipment - communication protocols - Metering Data Management Systems (MDMS) - Application of SGs - Interconnections issues between SGs

References:

1. N. Hatziargyriou, *Microgrids: Architectures and Control*, Wiley-IEEE Press, 1st Edition, 2014
2. J. N. Twidell &A. D. Weir, *Renewable Energy Sources*, University press ,Cambridge, 2001
3. James Larminie , Andrew Dicks , *Fuel Cell Systems,* John Weily & Sons Ltd, 2000
4. J. F. Manwell , J. G. McGowan, A. L. Rogers , *Wind Energy Explained*, John Weily & Sons Ltd 2009
5. Loi Lei Lai, Tze Fun Chan, *Distributed Generation- Induction and Permanent Magnet Generators*, IEEE Press, John Wiley & Sons, Ltd., England. 2007.
6. Amirnaser Yezdani, and Reza Iravani, *Voltage Source Converters in Power Systems: Modeling, Control and Applications*, IEEE John Wiley Publications, 2009.

EE6222D WIDE AREA MONITORING & CONTROL OF POWER SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Explain Synchrophasor Measurement Techniques
CO2: Implement and test wide area measurement systems
CO3: Realize optimal placement of PMU and state estimation using PMU data
CO4: Monitor, analyse and control power system conditions in real time

Module 1: (11 hours)

Phasor Measurement Techniques: Basic Concepts and Definitions SCADA vs PMU, Synchrophasors, Frequency, and ROCOF, Steady-State and Dynamic Conditions in Power Systems, Classical Phasor Versus Dynamic Phasor, Basic Definitions of Accuracy Indexes, Algorithms for Synchrophasors, Frequency, and ROCOF, Methods to Calculate Synchrophasors based on a Steady-State Model and Dynamic Signal Model, Evaluation of Frequency and ROCOF, Dynamic Behavior of Phasor Measurement Algorithms

Module 2: Phasor Measurement Units and Phasor Data Concentrators (10 hours)

Phasor measurement units and Phasor data concentrators: WAMS architecture, Sensors for PMUs, International Standards for Instrument Transformers, Accuracy of Instrument Transformers, Transducer Impact on PMU Accuracy, Hardware for PMU and PMU Integration, PMU Architecture, Data Acquisition System, Synchronization Sources, Communication and Data Collector, Distributed PMU, International Standards for PMU and Tests for Compliance, IEC 61850

Module 3: (10 hours)

State Estimation and PMUs: Formulation of the SE Problem, Network Observability-SE Measurement Model, SE Classification, State estimation with phasor measurents, Linear state estimation, Dynamic estimators.

Optimal PMU placement, meta-heuristic and deterministic algorithms, Integer Linear Programming Technique

Module 4: (10 hours)

WAMS applications- real-time analysis and technologies to detect, locate and characterize power system disturbances, monitoring power system oscillatory dynamics- Interpretation and visualization of wide-area PMU measurements, power system control with phasor feedback, discrete event control.
References:

1. Antonello Monti, Carlo Muscas, Ferdinanda Ponci, *Phasor Measurement Units and Wide Area Monitoring Systems*, Academic Press, 2016
2. A.G. Phadke, J.S. Thorp, *Synchronized Phasor Measurement and Their Applications*, Springer 2008
3. Yong Li, Dechang Yang, Fang Liu, Yijia Cao, Christian Rehtanz, *Interconnected Power Systems: Wide-Area Dynamic Monitoring and Control Applications*, Springer, 2015
4. Ali Abur, Antonio Gómez Expósito, *Power System State Estimation: Theory and Implementation*, CRC Press, 2004

5. Ma J., Makarov Y., Dong Z, *Phasor Measurement Unit and its Applications on Modern Power Systems*, Springer, 2010
6. IEEE Power & Energy Society, *IEEE Standard for Synchrophasor Data Transfer for Power Systems*, IEEE New York, 2011
7. Xu B, Abur A, *Optimal Placement of Phasor Measurement units for State Estimation*, PSERC, Final Project Report, 2005
8. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed. John Wiley & Sons, 2008
9. P. Kundur, *Power System Stability and Control,* McGraw Hill, New York, 1994.

EE6221D POWER QUALITY ISSUES AND REMEDIAL MEASURES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain various power quality issues, remedial measures and standards.
CO2: Develop models and analyse harmonics in networks and components
CO3: Design active power factor correction based on static VAR compensators and its control techniques
CO4: Analyze series and shunt active power filtering techniques for harmonic cancellation and isolation
CO5: Explain voltage quality improvement techniques and NEC grounding requirements and solutions to grounding and wiring problems

Module 1: (8 hours)

Introduction-power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-power quality measures and standards-THD-TIF-DIN-C-message weights-flicker factor transient phenomena-occurrence of power quality problems-power acceptability curves-IEEE guides, standards and recommended practices

Module 2: (10 hours)

Harmonics-individual and total harmonic distortion-RMS value of a harmonic waveform-triplex harmonics-important harmonic introducing devices-SMPS-Three phase power converters-arcing devices saturable devices-harmonic distortion of fluorescent lamps-effect of power system harmonics on power system equipments and loads. Modeling of networks and components under non-sinusoidal conditions transmission and distribution systems-shunt capacitors-transformers-electric machines-ground systems-loads that cause power quality problems-power quality problems created by drives and its impact on drives.

Module 3: (11 hours)

Power factor improvement- Passive Compensation- Passive Filtering- Harmonic Resonance- Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End Converters, Control Methods for Single Phase APFC- Three Phase APFC and Control Techniques- PFC Based on boost conversion technique and Bilateral Single Phase and Three Phase Converters. Static VAR compensators- SVC and STATCOM.

Module 4: (10 hours)

Active Harmonic Filtering-Shunt Injection Filter for single phase, three-phase three-wire and three-phase four-wire systems. d-q domain control of three phase shunt active filters- series active power filtering techniques for harmonic cancellation and isolation. Uninterruptible Power Supplies- Constant Voltage Transformers - Dynamic Voltage Restorers for sag , swell and flicker problems. Grounding and wiring - introduction - NEC grounding requirements- reasons for grounding-typical grounding and wiring problems-solutions to grounding and wiring problems.

References:

1. G.T. Heydt, *Electric power quality*, McGraw-Hill Professional, 2007.
2. Math H. Bollen, *Understanding Power Quality Problems*, IEEE Press, 2000.
3. J. Arrillaga, *Power System Quality Assessment*, John wiley, 2000.
4. J. Arrillaga, B.C. Smith, N.R. Watson & A. R.Wood, *Power system Harmonic Analysis*, Wiley, 1997.
5. E Fuchs, M.A.S. Masoum, *Power Quality in Power Systems and Electrical Machines*, Elsevier Inc., 2008.

A. Moreno, *Power Quality-Mitigation Technologies in a disturbed environment*, Springer, 2007.
6. W.E.Kazibwe, M.H.Sendaula, *Electric Power Quality Control Techniques*, Van Nostrand Reinhold, 1993.
7. IEEE Transaction and IET Journal papers

EE6301D POWER ELECTRONIC CIRCUITS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Analyse and design the Diode rectifiers and filters circuits
CO2: Design and implement various types of controlled rectifiers
CO3: Explain about various PWM techniques of 2-level DC to AC converters
CO4: Evaluate and design inverters with advanced PWM techniques
CO5: Design current controlled voltage source inverters

Module 1: Line Frequency Uncontrolled and Controlled Rectifiers and Inverters (13 hours)

C / LC filter Design for Single Phase diode rectifiers. Three Phase half wave rectifier with resistive load . Three phase full wave rectifier . Double Y type rectifier. Three Phase Rectifier Circuits. Input Line Current Harmonics and power factor. Line Notching and its control.

Single Phase: Half Wave Controlled Rectifier with R, RL, RLE loads, With Freewheeling diode. Full Wave Controlled Rectifier with various kinds of loads .Half Controlled and Full Controlled Bridges with passive and active loads - Input Line Current Harmonics and Power Factor- Inverter Mode of Operation.

Three Phase: Half Wave Controlled rectifier with RL Load . Half Controlled Bridge with RL Load . Fully Controlled Bridge with RL Load. Input Side Current Harmonics and Power Factor - Dual Converters . Circulating Current Mode and Non-Circulating Current Mode .

Module 2: Switch-Mode dc-ac Inverters (13 hours)

Basic Concepts . Single Phase Inverters. PWM Principles . Sinusoidal Pulse Width Modulation in Single Phase Inverters . Choice of carrier frequency in SPWM . Spectral Content of output . 3rd Harmonic injection to enhance the source utilisation. Bipolar and Unipolar Switching in SPWM - Blanking Time Maximum Attainable DC Voltage Switch Utilization .Reverse Recovery Problem and Carrier Frequency Selection . Output Side Filter Requirements and Filter Design - Ripple in the Inverter Output - DC Side Current.
Three Phase Inverters -Three Phase Square Wave /Stepped Wave Inverters . Three Phase SPWM Inverters . Choice of Carrier Frequency in Three Phase SPWM Inverters . Output Filters . DC Side Current . Effect of Blanking Time on Inverter Output Voltage .

Module 3: Introduction to high power converters (13 hours)

Converters for High Power Applications: Standard Modulation Strategies - Programmed Harmonic Elimination . Multi-Pulse Converters and Interface Magnetics - Space Vector Modulation – Minimum ripple current PWM method. Current Regulated Inverter – Current Regulated PWM Voltage Source Inverters . Methods of Current Control. Hysteresis Control . Variable Band Hysteresis Control . Fixed Switching Frequency Current Control Methods . Switching Frequency Vs accuracy of Current Regulation Areas of application of Current Regulated VSI .

Textbooks and References:

1. Ned Mohan *“Power electronics : converters, applications, and design*” John Wiley and Sons, 2006

2. P.C. Sen "*Power Electronics*" Tata McGraw Hill, 2003.
3. G.K.Dubey "*Thyristorised Power Controllers*" Wiley Eastern Ltd., 2005
4. Dewan & Straughen *"Power Semiconductor Circuits"* John Wiley &Sons., 1975 .
5. M.D.Singh & K.B.Khanchandani "*Power Electronics*" Tata McGraw Hill., 2007
6. B. K Bose '*Modern Power Electronics and AC Drives'*. Pearson Education (Asia)., 2007,09

EE6303D DYNAMICS OF ELECTRICAL MACHINES

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1: Formulate electrodynamic equations for the electrical machines.

CO2: Analyse the performance of the electrical machines using the electrodynamic equations.

CO3: Develop power invariant transformations for the dynamic analysis of electrical machines.

CO4: Carryout Stability analysis of the electrical machines under small signal and transient conditions.

Module 1: (12 hours)

Electrodynamic equations and their solution - a spring and plunger system - rotational motion system - mutually coupled coils - lagrange's equation - application of lagrange's equation to electromechanical systems - solution of electrodynamic equations by euler's and runge-kutta methods - linearisation of the dynamic equations and the small signal stability - differential equations and solutions - a smooth air-gap two winding machine - a two phase machine with current excitation - interpretation of the average power conversion conditions in terms of air-gap magnetic fields - primitive 4 winding commutator machine - commutator primitive machine - brush axis and its significance - self and mutually induced voltages in the stationary and commutator windings - speed emf induced in commutator winding - rotational inductance coefficients - sign of speed emf terms in the voltage equation - complete voltage equation of primitive 4 winding commutator machine - torque equation - analysis of dc machine using the primitive machine equations.

Module 2: (9 hours)

Three phase induction motor - equivalent two phase machine by mmf equivalence - equivalent two phase machine currents from three phase machine currents - power invariant phase transformation - voltage transformation - voltage and torque equations of the equivalent two phase machine - commutator transformation and its interpretation - transformed equations - different reference frames for induction motor analysis - nonlinearities in machine equations - equations under steady state - linearised equations of induction machine - small signal and transient stability analysis - eigen values - transfer function formulation.

Module 3: (9 hours)

Three phase salient pole synchronous machine - three phase to two phase transformation - voltage and torque equations in various reference frames - commutator transformation and transformed equations - parks transformation - suitability of reference frame - steady state analysis - large signal transient analysis - eigen values - general equations for small oscillations - small oscillation equations in state variable form - damping and synchronizing torques - small oscillation stability analysis - application of small oscillation models in power system dynamics.

Module 4: (9 hours)

Dynamic analysis of interconnected machines - machine interconnection matrices - transformation of voltage and torque equations using interconnection matrices - large signal transient analysis using transformed equations - small signal model using transformed equations - dc generator-motor system -

synchronous generator-motor system -ward-leonard system - hunting analysis of interconnected machines - selection of proper reference frame for individual machines in an interconnected system.

References:

1. D P Sengupta & J.B. Lynn, '*Electrical Machine Dynamics'*, The Macmillan Press Ltd. 1980.
2. R Krishnan, '*Electric Motor Drives, Modeling, Analysis and Control'*, Pearson Education, 2001.
3. P.C. Kraus, '*Analysis of Electrical Machines'*, McGraw Hill Book Company,1987.
4. I. Boldia & S A Nasar, '*Electrical Machine Dynamics'*, The Macmillan Press Ltd. 1992.
5. C.V. Jones, '*The Unified Theory of Electrical Machines'*, Butterworth, London. 1967.

EE6321D POWER SEMICONDUCTOR DEVICES AND MODELLING

Pre-requisite: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course outcomes:
CO1: Explain the basics of power semiconductor switches.
CO2: Illustrate the working of various types of converters and application of them.
CO3: Design the drive circuits for various Power Semiconductor Switches.
CO4: Model the converters and semiconductor switches.
CO5: Design the control of various power semiconductor switches.

Module 1: (10 hours)

Power Diodes. Basic Structure and I-V Characteristics. Breakdown Voltages and Control. On State Losses. Switching Characteristics. Turn on Transient . Turn off Transient . Reverse Recovery Transient . Schottky Diodes .Snubber Requirements for Diodes and Diode Snubbers. Thyristors - Basic Structure . V-I Characteristics . Turn on Process . On State operation . Turn off process

.Switching Characteristics .Turn on Transient and di/dt limitations . Turn off Transient . Turn off time and reapplied dv/dt limitations. Ratings of Thyristors. Snubber Requirements and Snubber Design. Triacs . Basic Structure and operation . V-I Characteristics .Ratings . Snubber Requirements.

Gate Turnoff Thyristor (GTO). Basic Structure and Operation. GTO Switching Characteristics. GTO Turn on Transient . GTO Turn off Transient. Minimum ON and OFF State times .Maximum Controllable Anode Current. Over current protection of GTOs

Module 2:**(13 hours)**

Power BJTs . Basic Structure and I-V Characteristics. Breakdown Voltages and Control .

Second Breakdown and its Control- FBSOA and RBSOA Curves - On State Losses . Switching

Characteristics.

Resistive Switching Specifications. Clamped Inductive Switching Specifications. Turn on Transient. Turnoff Transient . Storage Time .Base Drive Requirements . Switching Losses . Device Protection-Snubber. Requirements for BJTs and Snubber Design - Switching Aids.

Power MOSFETs - Basic Structure . V-I Characteristics . Turn on Process . On State operation . Turn off process . Switching Characteristics . Resistive Switching Specifications . Clamped Inductive Switching Specifications - Turn on Transient and di/dt limitations . Turn off Transient . Turn off time . Switching Losses . Effect of Reverse Recovery Transients on Switching Stresses and Losses - dv/dt limitations .

Gating Requirements . Gate Charge - Ratings of MOSFETs. FBSOA and RBSOA Curves . Device Protection –Snubber Requirements .

Insulated Gate Bipolar Transistors (IGBTs) . Basic Structure and Operation .Latch up IGBT Switching Characteristics . Resistive Switching Specifications . Clamped Inductive Switching Specifications – IGBT

Turn on Transient. IGBT Turn off Transient- Current Tailing - Ratings of MOSFETs. FBSOA and RBSOA Curves . Switching Losses - Minimum ON and OFF State times - Switching Frequency Capability – Over current protection of IGBT. Short Circuit Protection .Snubber Requirements and Snubber Design.

Module 3: **(7 hours)**

New power semiconductor devices . Thermal design of power electronic equipment .Modelling of power semiconductors (principles). Simulation tools

Module 4: **(9 hours)**

Gating Requirements for Thyristor, Component Temperature Control and Heat Sinks . Control of device temperature .heat transfer by conduction. transient thermal impedance - heat sinks .heat transfer by radiation and convection - Heat Sink Selection for SCRs and GTOs.

Modelling of power diode - Modelling of power MOSFET - Modelling of bipolar transistor - Modelling of IGBT

Text Books and References:

1. Ned Mohan, "*Power Electronics*",John Wiley and Sons,2006
2. G. Massobrio, P. Antognet," *Semiconductor Device Modeling with Spice*", McGraw-Hill, Inc.,1988.
3. B. J. Baliga," *Power Semiconductor Devices*",Thomson, 2004.
4. V. Benda, J. Gowar, D. A. Grant," *Power Semiconductor Devices. Theory and Applications*", John Wiley & Sons1994.99

EE6322D STATIC VAR CONTROLLERS AND HARMONIC FILTERING

Pre-requisite: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course outcomes:

CO1: Explain the fundamental principles of Passive and Active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.
CO2: Illustrate various single phase and three-phase Static VAR Compensation Schemes and their controls.
CO3: Develop models of Static VAR systems with a view towards Controller Design.
CO4: Demonstrate the fundamental principles of Passive and Active Harmonic Filtering in Power Systems
CO5: Analyse various single-phase and three-phase active harmonic filtering systems employing Current-regulated PWM VSI and their control.
CO5: Analyse and Model Active Harmonic Filtering systems with a vision towards Controller Design.

Module 1 : (10 hours)

Fundamentals of Load Compensation , Steady-State Reactive Power Control in Electric Transmission Systems , Reactive Power Compensation and Dynamic Performance of Transmission Systems . Power Qulity Issues. Sags, Sweels, Unbalance, Flicker, Distortion , Current Harmonics - Sources of Harmonics in Distribution Systems and Ill Effects .

Module 2: **(10 hours)**

Static Reactive Power Compensators and their control . Shunt Compensators, SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control, Series Compensators of Thyristor Switched and Controlled Type and their Control, SSSC and its Control, Sub-Synchronous Resonance and damping, Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power Systems.

Module 3: **(10 hours)**

Converters for Static Compensation . Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM) . GTO Inverters . Multi-Pulse Converters and Interface Magnetics . Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies (includes SVM) . Multi-level inverters of Cascade Type and their modulation. Current Control of Inverters.

Module 4: **(9 hours)**

Passive Harmonic Filtering . Single Phase Shunt Current Injection Type Filter and its Control, Three Phase Three-wire Shunt Active Filtering and their control using p-q theory and d-q modelling . Three-phase four wire shunt active filters . Hybrid Filtering using Shunt Active Filters . Series Active Filtering in Harmonic Cancellation Mode . Series Active Filtering in Harmonic Isolation Mode . Dynamic Voltage Restorer and its control . Power Quality Conditioner

Text Books and References:

1. T.J.E Miller. ‘*Reactive Power Control in Electric Systems*’, John Wiley & Sons,1982.
2. N.G. Hingorani & L. Gyugyi ‘*Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*’. IEEE Press, 2000.
3. Ned Mohan. ‘*Power Electronics*’. John Wiley and Sons 2006

EE6325D LINEAR AND DIGITAL ELECTRONICS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course outcomes:

CO1: Demonstrate the operation of BJT and CMOS operational amplifiers with special emphasis on non-ideal effects like offsets, finite impedance levels, finite gain bandwidth product, slew rate, PSRR etc.
CO2: Design various linear applications of opamps, various filters, sinusoidal oscillators etc., to carry out projects in Power Electronics.
CO3: Analyse and Design various nonlinear applications of opamps and comparators such as regenerative comparators, waveform generators, precision rectifiers, log-antilog amps etc.
CO4: Invent Power Electronic systems having VCOs, VFCs, FVCs, PLLs, ADCs, DACs, IC Multipliers/Dividers, OTAs etc.
CO5: Design combinational digital circuits using MUX, ROM, PLA, PAL etc.
CO6: Evaluate and devise synchronous and asynchronous sequential digital circuits.

Module 1: **(14 Hours)**

BJT and MOSFET Differential amplifiers and their analysis, Offset behaviour, Current sources for biasing inside a BJT/MOS IC –Properties of ideal Opamps, Internal description of a BJT Opamp, slew rate, internal description of a two stage MOS Opamp, Internal description of a Folded Cascode MOS Opamp, Dominant pole compensation –internal and external compensation.

The IOA model of an Opamp, principle of virtual short, Offset model for an Opamp, analysis and design of standard linear applications of Opamps Reference diodes and voltage references, linear voltage regulators Sinusoidal oscillators using Opamps

Active filtering – Butterworth low pass filter functions - low pass filter specifications - Order and cut off frequency of Butterworth function from low pass specifications –Sallen and Key second order LP section - gain adjustment in Butterworth LP filters –Butterworth high pass filters –

Second order wide band and narrow band band pass filters - multiple feedback single OPAMP LPF, HPF and BPF State variable active filter, Universal active filter.

Module 2: **(9 Hours)**

Regenerative Comparators, Comparator ICs , Square-Triangle – ramp generation, sine wave shaping, Function generator ICs , VCO Circuits, VFCs and FVCs and applications, Mono stable and Astable using Opamps, PLL and applications.

Precision rectification, Log and Anti-log amplifiers, IC multipliers, Trans conductance multiplier/divider, Time division multipliers

Analog switches - sample and hold amplifier –Data conversion fundamentals - D/A conversion – weighed resistor DAC - R/2R ladder DAC - current switching DAC - A/D conversion - quantiser characteristics - single slope and dual slope ADCs - successive approximation ADC - simultaneous ADC

Module 3: **(9 Hours)**

Basic digital circuits: Review of number systems and Boolean algebra - Simplification of functions using Karnaugh map - Boolean function implementation. . Examples of useful digital circuits:

Arithmetic Circuits, Comparators and parity generators, multiplexers and de multiplexers, decoders and encoders.

Combinational logic design: Combinational circuit design using Multiplexer, ROM, PAL, PLA.

Introduction to Sequential circuits: Latches and flip-flops (RS, JK, D, T and Master Slave) - Design of aclocked flip-flop – Flip-flop conversion - Practical clocking aspects concerning flip-flops.

Module 4: **(7 Hours)**

Design and analysis of sequential circuits: General model of sequential networks - State diagrams – Analysis and design of Synchronous sequential Finite Sate Machine – State reduction – Minimization and design of the next state decoder.

Counters: Design of single mode counters and multimode counters – Ripple Counters – Ring Counters – Shift registers counter design.

Practical design aspects: Timing and triggering considerations in the design of synchronous circuits – Setup time - Hold time – Clock skew.

Asynchronous sequential logic: Analysis and Design – Race conditions and Cycles – Hazards in combinational circuits – Hazard free realization.

Text Books and References:

1. Sedra & Smith: '*Microelectronic Circuits'*, Oxford University Press, 2004
2. Millman J.: Microelectronics, McGraw Hill,1999
3. Anvekar D.K. & Sonde B.S: '*Electronic Data Converters'*, Tata McGraw Hill,1994
4. Gayakwad R.A: '*OPAMPS & Linear Integrated Circuits'*, Prentice Hall of India,2002
5. Clayton G.B: '*Operational Amplifiers',* ELBS,2002
6. Frederiksen T.M: '*Intuitive Operational Amplifiers'*, McGraw Hill,1988
7. Roth C.H., '*Fundamentals of Logic Design'*, Jaico Publishers. IV Ed, 2003
8. W. I. Fletcher, '*An Engineering Approach to Digital Design'*, Prentice-Hall, Inc., Englewood Cliffs, NJ,1980
9. Tocci, R. J. and Widner, N. S., '*Digital Systems - Principles and Applications'*, Prentice Hall, 7th Ed, 200

EE6327D IMPLEMENTATION OF DSP ALGORITHMS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Illustrate the architecture of DSP systems, various transforms and algorithms in DSP.
CO2: Analyse and design digital filters and implement them.
CO3: Explain about Quantization Noise, and significance of Sampling rate and its conversion.
CO4: Design DSP algorithms and implement in PDSP / FPGA systems.

Module 1 TRANSFORMS (13 hours)

Overview of Digital Signal Processing, Introduction to MATLAB , Applications of Digital Signal Processing; Discrete-time signals and systems - Discrete-time Signals, Discrete Systems, Convolution, Difference Equations; The Discrete-Time Fourier Analysis - The Discrete-Time Fourier Transform (DTFT), The Properties of the DTFT, The Frequency Domain Representation of LTI Systems, Sampling and Reconstruction of Analog Signals; The *Z*-Transform - The Bilateral *Z*-Transform, Important Properties of the *Z*-Transform, Inversion of the *z*-Transform, System Representation in the *Z*-Domain, Solutions of the Difference Equations; The Discrete Fourier Transform - The Discrete Fourier Series, Sampling and Reconstruction in the *Z*-Domain, The Discrete Fourier Transform, Properties of the Discrete Fourier Transform, Linear Convolution Using the DFT, The Fast Fourier Transform.

Module 2: DIGITAL FILTER IMPLEMENTATION (14 hours)

Implementation of discrete-time filters - Basic Elements, IIR Filter Structures, FIR Filter Structures, Lattice Filter Structures, Overview of Finite-Precision Numerical Effects, Representation of Numbers, The Process of Quantization and Error Characterizations, Quantization of Filter Coefficients; FIR filter design - Preliminaries, Properties of Linear-phase FIR Filters, Window Design techniques, Frequency Sampling Design Techniques, Optimal Equiripple Design Technique, IIR filter design, Some Preliminaries, Some Special Filter Types, Characteristics of Prototype Analog Filters, Analog-to-Digital Filter Transformations, Lowpass Filter Design, Frequency-band Transformations.

Module 3: SAMPLING RATE CONVERSION (12 hours)

Introduction, Decimation by a Factor *D,* Interpolation by a Factor *I,* Sampling Rate Conversion by a Rational Factor *I/D,* FIR Filter Designs for Sampling Rate Conversion, FIR Filter Structures for Sampling Rate Conversion; Round-off Effects in Digital Filters - Analysis of A/D Quantization Noise, Round-off Effects in IIR Digital Filters, Round-off Effects in FIR Digital Filters; Applications in Adaptive Filtering - LMS Algorithm for Coefficient Adjustment, System Identification or System Modeling, Suppression of Narrowband Interference in a Wideband Signal, Adaptive Line Enhancement, Adaptive Channel Equalization.

Note : Use MATLAB as a tool to implement all these DSP concepts and obtain the resulting plots. Convert this Matlab code and implement in PDSP and / or FPGA systems.

Textbooks and References:

1. Vinay K. Ingle ,John G. Proakis : '*Digital Signal Processing Using MATLAB®*', Cengage Learning - Third Edition, ISBN-13: 978-1-111-42737-5.

2. Dimitris G Manolakis, John G. Proakis: '*Digital Signal Processing : Principles, Algorithms, and Applications*', 4th Edition, Pearson, 2007, ISBN: 9788131710005, 8131710009.
3. Hazarathaiah Malepati: '*Digital Media Processing: DSP Algorithms Using C*', Elsevier Science Publisher, ISBN: 9781856176781, 1856176789.
4. Sanjit K Mitra, '*Digital Signal Processing: A computer-based approach*', TataMc Grow-Hill edition.1998.
5. Dimitris G .Manolakis, Vinay K. Ingle and Stephen M. Kogon, '*Statistical and Adaptive Signal Processing*', Mc Grow Hill international editions .-2000
6. Alan V . Oppenheim, Ronald W. Schafer, '*Discrete-Time Signal Processing*', Prentice-Hall of India Pvt. Ltd., New Delhi, 1997
7. John G. Proakis, and Dimitris G. Manolakis, '*Digital Signal Processing*'(third edition), Prentice-Hall ofIndia Pvt. Ltd, New Delhi, 1997
8. Emmanuel C. Ifeachor, Barrie W. Jervis , '*Digital Signal Processing-A practical Approach*', Addison Wesley,1993
9. Abraham Peled and Bede Liu, '*Digital Signal Processing - Theory, Design and Implementation*', John Wiley and Sons, 1976

EE6329D ADVANCED MICROPROCESSOR BASED SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Illustrate the working of advanced microprocessors/controllers.
CO2: Program a processor in assembly language and develop an advanced processor based system.
CO3: Configure and use different peripherals in a digital system.
CO4: Explain how to compile, debug and execute Programs.

Module 1: Introduction (8 hours)

Technology trend in microprocessors - performance measurement –Comparing and summarizing performance - quantitative principles of computer design – Amdahl's law - Case studies.

History of the x86 family - Instruction Set architecture of a typical advanced x86 processor – using MASM32 for 32 bit assembly programming of x86 architectures

Module 2: 80386 to Pentium (8 hours)

Enhancements of 80386, Hardware Features, Protected virtual addressing mode -Virtual Memory, Memory Management Unit, Converting a Logical Address to a Physical Address, Calculating the size of the Logical Address Space, Protection, Multi Tasking, Interrupts of 80386, Privileged Instructions, The Enhanced Features of 80486, Data Alignment, The Pentium Processor, Pentium Pro, Pentium-II And Pentium-III, Pentium-IV, Latest Trends in Microprocessor Design

Module 3: ARM Introduction and Pipeline structures (13 hours)

Instruction Set Architecture (ISA) and ARM History, ARM architecture, Stack implementation in ARM, Endians, ARM organization and Implementation, Different Types of Instructions, ARM Instruction Set and Thumb Instruction set. Thumb state, Thumb Programmers model, Thumb Implementation, Thumb Applications. Thumb Instructions, Assembly Language Programming, condition codes, Data processing Instructions, High- Level Language Programming, System Development using ARM. Pipeline Hazards Interrupts and Exceptions, Exception Handlers, Reset Handling. Aborts, software Interrupt Instruction, undefined instruction exception. Interrupt Handling schemes, Interrupt Latency.

Module 4: ARM Memory and Hardware interfacing. (10 hours)

Memory Hierarchy, Cache and Memory Management and Protection, Digital Signal Processing on ARM, Peripheral Programming and system design for a specific ARM processor (ARM7/9), PWM generation and Motor control using ARM processor board. .

Textbooks and References

1. Lyla B.Das '*The x86 Microprocessors –Architecture Programming and Interfacing -8086 to Pentium*', Pearson Education , 2010.
2. Daniel W. Lewis , '*Fundamentals of Embedded Software with the ARM Cortex-M3'*, PEARSON, 1st Edition, 2015, ISBN: 9789332549937, 9332549931
3. Jonathan W Valvano, '*Embedded Systems: Introduction to Arm® Cortex(TM)-M3 Microcontrollers'* ,

2012.

4. Vincent Mahout, '*Assembly Language Programming: ARM Cortex-M3'* , Wiley , 2012
5. Jurij Silc, Borut Rob c, Theo Ungerer .Processor Architecture –From DataFlow to Super scalar and Beyond
6. Shibu K.V. Introduction to Embedded Systems Tata McGraw Hill, 2009
7. Robert Ashby *Designer's Guide to the Cypress PSoC Newnes* (An imprint of Elsevier), 2006
8. Sloss, Symes, Wright, ARM System Developer's Guide, Elsevier, 2014, ISBN: 9781493303748.
9. Oliver H. Bailey, *The Beginner's Guide to PSoC Express* Timelines Industries Inc.
10. Van Ess, Currie and Doboli Laboratory Manual for Introduction to Mixed-Signal, Embedded Design, Alphagraphics, USA
11. Steve Furber *ARM System-on-chip Architecture* ,Second Edition Pearson Education,2007
12. William Hohl ARM Assembly Language Programming CRC Press,2009
13. Andrew Sloss, Dominic Symes, Christ Wright, *ARM System Developer's guide –Designing and optimizing software* Elseiver Publishers ,2008
14. Andrew N. SLOSS, Dominic *SYMES and Chris WRIGHT: ARM System Developers Guide*, Designing and Optimizing System Software. ELSEVIER, 2004
15. Steve Furber*, ARM System-on-Chip Architecture*, Second Edition, PEARSON, 2013
16. Manuals and Technical Documents from the ARM Inc, web site.
17. Hennesy J. L. & Pattersen D. A., *Computer Architecture: A Quantitative approach*, 4/e, Elseiver Publications, 2007

EE6226D HYBRID AND ELECTRIC VEHICLES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Explain performance characteristic and model dynamics of hybrid and electric vehicles
CO2:Analyse the architecture of drive trains and electric propulsion units of electric and hybrid vehicles
CO3: Analyse various energy storage devices used in hybrid and electric vehicles and select the electric drive system
CO4: Explore energy management strategies used in hybrid and electric vehicles

Module 1: (9 hours)

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 characteristics, mathematical models to describe vehicle performance.

Module 2: (10 hours)

Hybrid and Electric Drive-trains: Basic concept of traction, introduction to various drive-train topologies, power flow control in drive-train topologies, fuel efficiency analysis.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.

Module 3: (10 hours)

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Analysis of various energy storage devices – Battery, Fuel Cell, Super, Flywheel - Hybridization of different energy storage devices.

Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor and power electronics, selecting the energy storage technology, Communications, supporting subsystems

Module 4: (10 hours)

Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification, comparison and implementation issues of energy management strategies.

Case Studies: Design of a Hybrid Electric Vehicle (HEV) and Battery Electric Vehicle (BEV).

References:

1. I. Husain, *Electric and Hybrid Electric Vehicles*, CRC Press, 2003
2. M. Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2005
3. A. E. Fuhs, *Hybrid Vehicles and the Future of Personal Transportation*, CRC Press, 2009
4. C. C. Chan and K. T. Chau, *Modern Electric Vehicle Technology, Oxford Science Publication*, 2001

5. G. Lechner and H. Naunheimer, *Automotive Transmissions: Fundamentals, Selection, Design and Application*, Springer, 1999
6. Gianfranco, *Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market*, Pistoia Consultant, Rome, Italy, 2010
7. M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, 3rd ed., Pearson, 2004
8. V. R. Moorthi, *Power Electronics: Devices, Circuits and Industrial Applications*, Oxford University Press, 2007
9. R. Krishnan, *Electric motor drives: modeling, analysis, and control*, Prentice Hall, 2001
10. P. C. Krause, O. Wasynczuk, S. D. Sudhoff, *Analysis of electric machinery*, IEEE Press, 1995
11. L. Guzella, A. Sciarretta, *Vehicle Propulsion Systems*, Springer, 2007

EE6304D MODERN DIGITAL SIGNAL PROCESSORS

Pre -Requisite: Nil

L	T	P	C
3	1	0	3

Total Hours: 39

Course Outcomes:

CO1: Design a system using digital signal processors
CO2: Analyse and understand digital signal processors architectures.
CO3 : Program various DSP processors using IDEs.
CO4: Utilise the advantages of modern digital signal processors for power electronic applications.

Module 1: Introduction to Digital Signal Processors (DSP) (12 hours)

Features of Digital Signal Processors, Modern trends in DSP: Von Newmann versus Harvard architecture, Architectures of superscalar and VLIW fixed and floating point processors, New Digital Signal Processing hardware trends, Selection of DS processors.

Internal details of DSP using Texas Instruments DSP (TMS330C6000 Series) as a tool: DSP Architecture, CPU Data Paths and Control, Internal Data/Program Memory. On chip peripherals and its programming details: Timers - Multi channel buffered serial ports - Extended Direct Memory Access, Interrupts, Pipelining.

Module 2: Programming the DSP (14 hours)

Texas Instruments IDE - C C Studio - Introduction to the C6713 DSK- Review of FIR filtering: FIR filter design techniques and tools, Review of IIR filtering: IIR filter design techniques and tools, Sampling, quantization and working with the AIC23 codec, Writing efficient code: optimizing compiler - effect of data types and memory map. TMS320C6713 Assembly language Programming: Instructions Set and Addressing Modes – Linear Assembly. Interfacing CC Studio with Matlab.

Module 3: Current trend in Digital Signal Processors (13 hours)

Motor Control Digital Signal Processing Solutions Using the TMS320F240DSP-Controller. Architecture of TMS320C2XX series DSP and its applications. Architecture trends of other DSP processors, Analog Devices DS processors: ADSP-2105 digital signal processor for motor control applications, Microchip dsPIC controllers for power electronics applications. Other major vendors in the DSP market and the latest trends.

References:

1. On-line TI materials for the TI C6713 DSK board: http://www.ti.com
2. Naim Dahnoun '*Digital Signal Processing Implementation using the TMS320C6000 DSP Platform'*, 1st Edition
3. R. Chassaing, '*Digital Signal Processing and Applications with the C6713 and C6416 DSK*', John Wiley and Sons, Inc., New York, 2004
4. Sen M. Kuo and Woon-Seng Gan. '*Digital Signal Processors: Architectures, Implementations, and Applications'*,
5. David J Defatta J, Lucas Joseph G & Hodkiss William S ; '*Digital Signal Processing: A System Design Approach*', 1st Edition; John Wiley
6. A.V. Oppenheim and R.W. Schafer, *Discrete-Time Signal Processing*, Second edition, Prentice-Hall,Upper Saddle River, NJ, 1989
7. John G Proakis, Dimitris G Manolakis*, Introduction to Digital Signal Processing*, 1st Edition.
8. On-line Microchip materials: http://www.microchip.com/design-centers/intelligent-power

EE6523D CONDITION MONITORING OF POWER EQUIPMENT

Prerequisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course outcomes:

CO1: Understand various condition monitoring methods for power equipment

CO2: Assess the condition of transformers in operation using various electrical and non-electrical methods

CO3: Assess the condition of cables using various techniques such as partial discharge measurement

CO4: Assess the condition of GIS using various techniques

Module 1: (8 hours)

Dielectric Response Measurement: Polarization Mechanisms in Dielectrics.
Dielectric Response in Time-Domain. Polarization and Depolarization Current (PDC) Measurement, its test set up and typical results. Recovery Voltage Measurement (RVM) fundamentals, RVM Spectrum, typical RVM results.
Dielectric Response in Frequency-Domain. Frequency Domain Spectroscopy (FDS), FDS equipment and analysis. FRA.

Module 2: (12 hours)

Condition monitoring of transformers: Chemical and electrical methods
Traditional Condition Assessment Techniques for Oil-Paper Composite Insulation: Dissolved Gas Analysis (DGA), Furan Analysis, Degree of Polymerization (DP).
Moisture in Oil-Paper Composite Insulation: Moisture Distribution, moisture Dynamics, effects of moisture, moisture detection – Crackle Test, Karl Fischer Titration (KFT), equilibrium curves, comparison of equilibrium curves, ABB and Serena's Equations, moisture content in paper, moisture management, oil reclamation.
Assessing the condition of transformers using FDS, PDC and RVM methods.

Module 3: (9 hours)

Condition monitoring of cables:
Detection and localization of defects in cables by Partial discharge analysis, impedance spectroscopy, acoustic and UHF sensors and time domain reflectometry (TDR)

Module 4: (10 hours)

Condition monitoring of GIS:
Analysis of SF_6 samples from GIS, Gas density monitoring- online condition monitoring of GIS gas tightness and SF_6 leakages, Partial discharge monitoring- Online insight in the condition of the dielectric strength of the GIS installation.

References:

1. Sivaji Chakravorti, Debangshu Dey, Biswendu Chatterjee, *Recent trends in the condition monitoring of transformers, Theory, Implementation and Analysis*, Springer Verlag London 2013.
2. R. E. James and Q. Su., *Condition Assessment of High Voltage Insulation in Power System Equipment*, IET Power and Energy Series, 2008.
3. Hermann Koch, *Gas Insulated Substations*, IEEE Press and John Wiley & Sons Ltd., 2014.

EE6202D POWER SYSTEM DYNAMICS AND CONTROL

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Design and analyze Automatic Generation control (AGC) and AVR for power systems considering economic dispatch.
CO2: Model and analyze dynamical systems to address various power system stability problems.
CO3: Execute digital simulation of large power system for small signal and transient stability analyses and develop stability enhancement methods.
CO4: Model and analyze voltage stability problem based on static and dynamic approach and develop stability enhancement methods.

Module 1: (10 hours)

Generation Control Loops. AVR Loop. Performance and Response. Automatic Generation Control of Single Area and Multi Area Systems. Static and Dynamic Response of AGC Loops – analysis using digital simulation - Economic Dispatch and AGC, AGC in a Deregulated Environment, Recent advances in AGC

Module 2: (10 hours)

Small signal angle instability (low frequency oscillations) - Power System Model for Low Frequency Oscillation Studies, damping and synchronizing torque analysis, Eigen value Analysis, Improvement of System Damping with Supplementary Excitation Control, Standard models for PSS representation-supplementary modulation control of FACTS devices, sub-synchronous frequency oscillations - Sub Synchronous Resonance and Countermeasures, IEEE Benchmark models for SSR studies

Module 3: (10 hours)

Transient Stability Problem, Modeling of Synchronous Machine, Loads, Network, Excitation Systems, Turbine And Governing Systems, Trapezoidal Rule of Numerical Integration Technique For Transient Stability Analysis, Simultaneous Implicit Approach for Transient Stability Analysis of Multi-machine Systems, Data For Transient Stability Studies, analysis using digital simulation - Transient Stability Enhancement Methods

Module 4: (9 hours)

Voltage Stability Problem. Real and Reactive Power Flow in Long Transmission Lines. Effect of ULTC and Load Characteristics on Voltage Stability. Voltage Stability Limit. Voltage Stability Assessment Using PV Curves. System Modelling-Static and Dynamic Analysis-Voltage Collapse Proximity Indices. Voltage Stability Improvement Methods.

References:

1. P. M. Anderson, A. A. Fouad, *Power system control and stability*, 2nd ed. John Wiley & Sons, 2008
2. P. Kundur, *Power System Stability and Control*, McGraw Hill, New York, 1994.
3. A.J. Wood, B.F. Wollenberg, *Power Generation, Operation And Control*, 2nd ed., John Wiley And Sons, New York, 1996.
4. O.I. Elgard, *Electric Energy System Theory: An Introduction*, 2nd ed., McGraw Hill, New York, 1982

5. K.R. Padiyar, *Power System Dynamics, Stability And Control*, Interline Publishing (P) Ltd., Bangalore, 1999
6. M A Pai, D P Sen Gupta, K R Padiyar, *Small Signal Analysis of Power Systems*, Narosa Series in Power and Energy Systems, 2004
7. Leonard L Grigsby, *Power Systems*, Electrical Power Engineering Handbook, CRC Press, New York, 2007.
8. C. Van Custem, T. Vournas, *Voltage Stability Of Electric Power Systems*, Rlever Academic Press
9. Yao-Nan-Yu, *Electric Power System Dynamics,* Academic Press, 1983
10. J. Arrilaga, C.P. Arnold, B.J. Harker, *Computer Modeling of Electrical Power Systems*, Wiley, New York, 1983.
11. I.J. Nagrath, O.P. Kothari, *Power System Engineering*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1994.

EC6421D DIGITAL IMAGE PROCESSING TECHNIQUES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Demonstrate the methods of image acquisition, representation and manipulation to design and develop algorithms for solving image processing problems related to various applications like medicine, industry, communications etc.

CO2: Analyze various image processing algorithms for preprocessing, restoration, compression and segmentation using various spatial and frequency domain methods

CO3: Identify and solve complex real world problems in image processing using modern signal processing tools, active cooperative learning and be able to demonstrate them effectively.

CO4: Acquire skills to conduct independent study and analysis of image processing problems and techniques that would engage in lifelong learning.

Module 1: (12 hours)

Image representation: Gray scale and colour Images, image sampling and quantization, colour spaces. Connectivity and relations between pixels.Simple manipulations of pixels - arithmetic, logical and geometric operations. Various techniques for image enhancement and restoration - filters in spatial and frequency domains, histogram-based processing, homomorphic filtering, Image Registration. Examples and case studies.

Module 2: (13 hours)

Morphological Image Processing: The structuring element, Basic operations on sets, Erosion, Dilation, Opening and Closing, Hit-or-Miss Transform, Basic Morphological Algorithms and applications.
Image segmentation: Edge detection, line detection, curve detection, Edge linking and boundary extraction, boundary representation, region representation and segmentation - Thresholding, Otsu's Method, Variable and multi variable thresholding, Similarity based Segmentation - Segmentation Using Morphological Watersheds, Use of Motion in Segmentation.Image representation and object recognition: Descriptors for boundaries and regions, global descriptors – Pattern recognition as applied to images.

Module 3: (14 hours)

Fundamental concepts of image compression - Compression models - Information theoretic perspective - Fundamental coding theorem - Lossless Compression: Huffman Coding- Arithmetic coding - Bit plane coding - Run length coding - Lossy compression: Quantization – Scalar and Vector, Transform coding - Image compression standards, Introduction to Sub band coding. Basic concepts of video compression, Introduction to video compression standards.

References:

1. R. C. Gonzalez, R. E. Woods, *Digital Image Processing*, Pearson Education. III Ed.,2016
2. Jain A.K., *Fundamentals of Digital Image Processing*, Prentice-Hall, 2002.
3. Jae S. Lim, *Two Dimensional Signal And Image Processing*, Prentice-Hall, Inc, 1990.
4. Pratt W.K., *Digital Image Processing*, John Wiley, IV Edition, 2007.
5. K. R. Castleman, *Digital image processing*, Prentice Hall, 1

EC6434D LINEAR & NONLINEAR OPTIMIZATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Outline an adequate mathematical background on optimization theory.
CO2: Analyze the basic techniques commonly used in linear programming problems.
CO3: Develop the basic skill to address the nonlinear programming problems.
CO4: Obtain the fundamental knowledge to oversee the constrained and unconstrained optimization problems.

Module 1: (10 hours)

Mathematical background: sequences and subsequences, mapping and functions, continuous functions infimum and supremum of functions minima and maxima of functions, differentiable functions. Vectors and vector spaces, matrices, linear transformation, quadratic forms, gradient and Hessian-Linear equations, solution of a set of linear equations, basic solution and degeneracy, convex sets and convex cones, convex hulls, extreme point, convex and concave functions, differentiable convex functions.

Module 2: (13 hours)

Linear Programming: introduction, optimization model, formulation and applications, classical optimization techniques: single and multi variable problems, types of constraints, graphical method, linear optimization algorithms: simplex method, basic solution and extreme point, degeneracy, primal simplex method, dual linear programs, primal, dual, and duality theory, dual simplex method, primal-dual algorithm. Post optimization problems: sensitivity analysis and parametric programming.

Module 3: (16 hours)

Nonlinear Programming: minimization and maximization of convex functions, local & global optimum, convergence. Unconstrained optimization: one dimensional minimization, elimination methods: Fibonacci & Golden section search, gradient methods. Constrained optimization: Lagrangian method, Kuhn-Tucker optimality conditions, convex programming problems. augmentedLagrangian method (ALM)

Applications of optimization theory in signal processing: signal processing via convex optimization, applications in weight design, linearizing pre-equalization, robust Kalman filtering, online array weight design, basic pursuit denoising (BPDN), compressing sensing and orthogonal matching pursuit (OMP).

References:

1. David G Luenberger, *Linear and Non Linear Programming.*, Addison-Wesley, 2^{nd}Edn., 2001
2. S.S.Rao, *Engineering Optimization.; Theory and Practice,* 4^{th} ed., John Wiley, 2013,
3. S.M. Sinha, *Mathematical programming: Theory and Methods*, Elsevier, 2006.
4. Hillier and Lieberman, *Introduction to Operations Research*, 8^{th} ed., McGraw-Hill, 2005.
5. Kalyanmoy Deb, *Optimization for Engineering: Design Algorithms and Examples*, Prentice Hall, 1998.
6. Igor Griva, ArielaSofer, Stephen G. Nash: *Linear and Nonlinear Optimization*, SIAM, 2009.

EC6431D PATTERN RECOGNITION AND ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (12 hours)

Introduction - features, feature vectors and classifiers, Classifiers based on Bayes Decision theory - discriminant functions and decision surfaces, Bayesian classification for normal distributions, Estimation of unknown probability density functions, the nearest neighbour rule. Linear classifiers - Linear discriminant functions and decision hyper planes.

Module 2: (15 hours)

The Perceptron algorithm, MSE estimation, Non-Linear classifiers- Two layer and three layer Perceptrons, Back propagation algorithm, Networks with Weight sharing, Polynomial classifiers, Radial Basis function networks, Support Vector machines, Decision trees, Boosting - combining classifiers.

Feature selection, Class separability measures, Optimal feature generation, The Bayesian information criterion, representation of images in spaces, KL transform, Nonlinear transform - kernel PCA, Isomap, LLE. Speech and audio features - Cepstrum, Mel-cepstrum, Spectral features. Context dependent classification - Bayes classification, Markov chain models, HMM, Viterbi Algorithm. Training Markov models on neural networks.

Module 3: (12 hours)

Datasets, training and testing methods, accuracy, Receiver Operating Characteristics (ROC) curveClustering- Cluster analysis, Proximity measures, Clustering Algorithms - Sequential algorithms, neural network implementation. Hierarchical algorithms - Agglomerative algorithms, Divisive algorithms, Probabilistic clustering, K - means algorithm. Clustering algorithms based on graph theory, Competitive learning algorithms, Valley seeking clustering, Clustering validity.

References:

1. C. Bishop, *Pattern Recognition and Machine Learning*, Springer, 1st ed. 2006
2. Richard O. Duda, Hart P.E, and David G Stork, *Pattern classification*, 2nd Edn., John Wiley & Sons Inc., 2001.
3. S Theodoridis, K Koutroumbas*, Pattern Recogntion*, 4th Edition, Academic Press, 2009.

MA6010D SIMULATION AND MODELLING

Pre-requisite: Knowledge of probability and statistics

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:

CO1. Learn the concept of simulation of stochastic system and continuous systems.
CO2. Evaluate a simulation experiment, validate a simulation experiments and also will be able to test the reliability of the simulation results.
CO3: The learner will be able to simulate queuing systems, PERT NETWORK, Inventory systems and similar stochastic systems.
CO4**:** Apply simulation and modeling for studying various real world systems.

Module I: (14 hours)

Introduction to system simulation -Introduction: Systems and models – Computer simulation and its applications. Continuous system simulation- Modelling continuous systems, simulation of continuous systems. Discrete system simulation- Methodology, event scheduling and process interaction approaches.
Random number generation – testing of randomness, generation of stochastic variates, Random samples from continuous distributions – Uniform distribution, Exponential distribution m-Erlang distribution, Gamma distribution, Normal distribution, Beta distribution, Random samples from discrete distributions – Bernoulli, Discrete uniform, Binomial, Geometric and Poisson.

Module II: (14 hours)

Evaluation of Simulation Experiments and Simulation Languages - Evaluation of simulation experimentsverification and validation of simulation experiments, Statistical reliability in evaluating simulation
experiments – Confidence intervals for terminating simulation runs - Simulation Languages: Programming Considerations – General features of GPSS, SIMSCRIPT and SIMULA.

Module III: (14 hours)

Simulation of Queuing Systems - Introduction – Parameters of queue, formulation of queuing problems, generation of arrival pattern, generation of service pattern, simulation of single server queues, simulation of multi-server queues, simulation of tandem queues. Computer simulation of Queuing systems.

Module IV: (14 hours)

Simulation of Stochastic Network - Introduction: Simulation of PERT Network – Definition of network diagrams, forward pass computation, simulation of forward pass, backward pass computations, simulation of backward pass, determination of float and slack times determination of critical path, simulation of complete network, merits of simulation of stochastic networks. Computer simulation of PERT network.

References:

1. Deo,N ,1989, *System Simulation and Digital Computer* , PHI, Delhi.
2. Gordan, G , 1990, *System Simulation* , PHI, Delhi.
3. Banks, J., Carson, J. S., and Nelson, B. L., 2000, *Discrete –Event System Simulation*, 2nd edn., PHI, New Delhi.
4. Law, A.M. and Kelton, W.D , 1990, *Simulation Modelling and Analysis* , Mc- Graw Hill.

MA7165D STATISTICAL DIGITAL SIGNAL PROCESSING

Pre-requisites: Nil

L	T	P	C
3	1	0	3

Total hours: 39

Course Outcomes:
CO1: Students acquire knowledge about random processes and their classification.
CO2: Learn and apply concepts of signal modelling.
CO3: Understand basic results about Lattice filters and Wiener filtering.
CO4: Learn about power spectrum estimation and application to real world problems.

Module 1: (10 hours)

Discrete-Time Random Processes: Random Variables, Random Processes, Filtering Random Processes, Spectral Factorization, Special Types of Random Processes.

Module 2: (12 hours)

Signal Modeling: The Least Squares Method, The Pade Approximtion, Prony's Method, Finite Data Records, Stochastic Models

Module 3: (17 hours)

Lattice Filters and Wiener Filtering: The FIR Lattice Filter, Split Lattice Filter, IIR Lattice Filters, Stochastic Modeling, The FIR Wiener Filter, IIR Wiener Filter, Discrete Kalman Filter.

Spectrum Estimation: Nonparametric Methods, Minimum Variance Spectrum Estimation, The Maximum Entropy Method, Parametric Methods, Frequency Estimation, Principal Components Spectrum Estimation.

References:

1. M. H. Hayes, '*Statistical Digital Signal Processing and Modeling*', John Wiley & Sons, 2004.
2. G. J. Miao and M. A. Clements, '*Digital Signal Processing and Statistical Classification*', Artech House, London, 2002.
3. R. M. Gray and L. D. Davisson, '*An Introduction to Statistical Signal Processing*', Cambridge University Press, 2004.

MA7166D STATISTICAL METHODS FOR QUALITY MANAGEMENT

Pre-requisite: Knowledge of probability and Statistics

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: learn various statistical tools for management.
CO2: learn the concept of design and analysis of experiments and will be able to apply different designs to handle different real world problems.
CO3: use appropriate control charts for the quality management in different cases
CO4: Use reliability analysis for scientific decision making.

Module I: (11 hours)

Design and analysis of experiments : Introduction to design and analysis of experiments. Single Factor design and Analysis of Variance. Randomized Blocks, Latin Squares and Related Designs. Introduction to Factorial Designs : Basic Definitions and Principles, The Two-Factor Factorial Design, The General Factorial Design, Fitting Response Curves and Surfaces, Blocking in a Factorial Design.

Module II : (9 hours)
Statistical process control : change and assignable causes of quality variation, setting up of operating control charts for X *and* R , Control charts for X and S, Control charts for individual measurements, Applications of variables control charts. Control charts for Attributes- control charts for Fraction nonconforming, control charts for nonconformities(defects).

Module III: (10 hours)

Cumulative sum and exponentially weighted moving average control charts- The cumulative-sum control charts, The exponentially weighted moving-average control charts, the moving average moving control charts. Statistical process control techniques, process capability analysis. Acceptance sampling for attributes.

Module IV: (10 hours)

Reliability Statistics: Reliability definition, availability, reliability bathtub curve, estimating MTBF, reliability prediction, confidence interval for MTBF, testing, system reliability, series systems, parallel systems, Baye's theorem applications, non-parametric and related test designs, hazard function, Weibul distribution, Log-normal distribution, stress- strength inference, Binomial confidence intervals, Arrhenius model, sequential testing.

References:

1. Grant E. L., and Leavenworth R. S., *Statistical Quality control*, 7th Ed.n; McGraw- Hill Companies Inc. 1996.
2. Montgomery D. C., *Introduction to Statistical Quality Control*, 4rd Edn., John Wiley and sons2000.
3. Montgomery D. C., *Design and Analysis of Experiments*, 8th Edn., John Wiley & Sons, Inc., 2012.
4. Dovich R. A., *Reliability statistics*, A S Q Quality Press., 1990.

MA7355D FUZZY SET THEORY AND APPLICATIONS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:
CO1: Provides the basic concepts in fuzzy sets and fuzzy relations.
CO2: Teaches techniques for converting a crisp data to fuzzy data and vice versa.
CO3: Enhancement of the ability to solve problems based on fuzzy arithmetic.
CO4: Training for handling fuzzy data using fuzzy measures.

Module I: Crisp sets and Fuzzy sets (10 hours)
Introduction – crisp sets an overview – the notion of fuzzy sets –basic concepts of fuzzy sets – membership functions – methods of generating membership functions – defuzzification methods- operations on fuzzy sets - fuzzy complement – fuzzy union – fuzzy intersection – combinations of operations – General aggregation operations.

Module II: Fuzzy arithmetic and Fuzzy relations (10 hours)
Fuzzy numbers- arithmetic operations on intervals- arithmetic operations on fuzzy numbers- fuzzy equations- crisp and fuzzy relations – binary relations – binary relations on a single set – equivalence and similarity relations – compatibility or tolerance relations.

Module III :Fuzzy measures (10 hours)
Fuzzy measures – belief and plausibility measures – probability measures – possibility and necessity measures – possibility distribution – relationship among classes of fuzzy measures.

Module IV: Fuzzy Logic and Applications (9 hours)
Classical logic : an overview – fuzzy logic – approximate reasoning – other forms of implication operations – other forms of the composition operations – fuzzy decision making –fuzzy logic in database and information systems – fuzzy pattern recognition – fuzzy control systems.

References:

1. George J Klir and Tina A Folger , *Fuzzy sets, Uncertainty and Information*, Prentice Hall of India, 1988.
2. H.J. Zimmerman, *Fuzzy Set theory and its Applications*, 4th Edition, Kluwer Academic Publishers, 2001.
3. Goerge J Klir and Bo Yuan, *Fuzzy sets and Fuzzy logic: Theory and Applications,* Prentice Hall of India, 1997.
4. Hung T Nguyen and Elbert A Walker, *First Course in Fuzzy Logic*, 2nd Edition , Chapman & Hall/CRC, 1999.
5. Jerry M Mendel, *Uncertain Rule – Based Fuzzy Logic Systems ; Introduction and New Directions*, PH PTR, 2000.
6. John Yen and Reza Langari, *Fuzzy Logic : Intelligence Control and Information*, Pearson Education, 1999.
7. Timothy J Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill International Editions, 1997.

MA8154D WAVELETS THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1: Review fundamental concepts of linear algebra and understand the theory of Fourier transform.
CO2: Acquire knowledge about construction of discrete wavelets.
CO3: Learn the construction of continuous wavelets through iteration and their implementation.
CO4: Study about multi resolution analysis and construction.

Module 1: (10 hours)

Vector spaces and Bases, Linear transformation, Matrices and change of basis, Inner products, Hilbert Space, Fourier transforms, Parseval identity and Plancherel theorem, Basic Properties of Discrete Fourier Transforms , Translation invariant Linear Transforms ,The Fast Fourier Transforms.

Module 2: (18 hours)

Construction of wavelets on ZN ,The Haar system, Shannon Wavelets, Real Shannon wavelets,Daubechie's D6 wavelets on ZN., Examples and applications.

Wavelets on Z:l2 (Z), Complete orthonormal sets in Hilbert spaces,L2 $(-\pi,\pi)$ and Fourier series, The Fourier Transform and convolution on l2 (Z), First stage Wavelets on Z , Implementation and Examples.

Module 3: (11 hours)

Wavelets on R : L^2 (R) and approximate identities, The Fourier transform on R , Multiresolution analysis, Construction of MRA .

References:

4. Michael. W. Frazier, *An Introduction to Wavelets through Linear Algebra*, Springer, Newyork, 1999.
5. Jaideva. C. Goswami, Andrew K Chan, *Fundamentals of Wavelets Theory Algorithms and Applications*, John Wiley and Sons, Newyork. , 1999.
6. Yves Nievergelt, *Wavelets made easy*, Birkhauser, Boston,1999.
7. G. Bachman, L.Narici and E. Beckenstein , *Fourier and wavelet analysis*, Springer, 2006.

MA8163D ADVANCED OPERATIONS RESEARCH

Prerequisite: Linear programming

L	P	G	C
3	0	0	3

Total hours: 42

Module I (12 hours)

Mathematical preliminaries. Maximum and Minimum-Quadratic forms-Gradient and Hessian matricesUnimodal functions-Convex sets-Convex and concave functions-Mathematical programming Problems.
Varieties and characteristics –Difficulties caused by nonlinearity- Role of convexity in Non linear programming- Unconstrained optimization-Search methods. Fibonacci search-Golden section search.

Module II (10 hours)

Hooke and Jeeve's Method –Optimal gradient method-Newtons method- Constrained nonlinear optimization-Constrained optimization with equality constraints-Lagrangian method-Sufficiency conditions- Optimization with inequality constraints- Kuhn-Tucker conditions- Sufficiency Conditions.

Module III (10 hours)

Quadratic programming- Separable programming-Frank and wolfe's method-Kelley'cutting plane method- Rosen's gradient projection method-Fletcher-Reeve's method-Penalty and Barrier method.

Module IV (10 hours)

Integer linear programming-Gomory's cutting plane method-Branch and Bound Algorithm- Travelling salesesman problem- knapsack problem- Introduction to optimization softwares.

References:

1.Taha.H.A. , *Operation Research-An introduction* , Prentice Hall, 6th Edn, 2006.
2.Simmons.D.M , *Nonlinear Programming for Operations Research* , Prentice Hall, 1993.
3.M.S.Bazaara, H.D Sherali,,C.M.Shetty, *Nonlinear Programming Theory and Algorithm* , John Wiley, 2003.

MA6011D DESIGN OF EXPERIMENTS

Pre-requisite: Statistical Methods

L	T	P	C
3	0	0	3

Total hours: 42

Course Outcomes:
CO1: Learn different designs of experiments and the analysis of the results from the outcomes of the experiments.
CO2: Apply completely randomized designs, randomized block designs, factorial designs in appropriate situations.
CO3: Prepare inference from the analysis results of different designs.
CO4: Learn Taguchi methods and will be able to use it in decision making related to quality management

Module I: (14 hours)
Introduction, Randomization, replication, local control, one way and two way classification with unequal and equal number of observations per cell (with / without interactions). Connectedness, balance, orthogonality, BIBD, ANOCOVA.

Module II: (14 hours)
2^k Full factorial experiments: diagramatic presentation of main effects and first and second order interactions, model, analysis of single as well as more than one replicates, using ANOVA. Total confounding of 2k design in 2p blocks, p ≥ 2. Partial confounding in 2p blocks, p =2, 3. Fractional factorial experiments. Resolution of a design, (III, IV & V), aberration of a design. Plackett-Burman design.
3^k designs: contrasts for linear and quadratic effects , statistical analysis of 3k design, confounding and fractional experiments in 3k design.

Module III: (14 hours)
Response surface methodology (RSM): linear and quadratic model, stationary point, Central composite designs(CCD), ridge systems, multiple responses, Concept of rotatable design, Spherical CCD, BoxBehnken design, face-centered CCD, equiradial designs, small composite designs, blocking in RSM, optimal designs, simplex lattice designs, simplex centroid designs.

Module IV: (14 hours)
Taguchi methods: concept of loss function, S/N ratio, orthogonal arrays, triangular tables, linear graphs, inner and outer arrays.
Random effect models and mixed models. Restricted and unrestricted mixed models. Nested and splitplot designs.

References:

1. John P.W.M., *Linear Models*, John Wiley Ltd., 1971.
2. Montgomery, D.C., *Design and Analysis of Experiments*, John Wiley, 2001.
3. Ogawa J., *Statistical Theory of the Analysis of Experimental Design*, Marcel Dekker, 1974.
4. Hicks, C.R. and Turner K.V., *Fundamental Concepts in the Design of Experiments* 5th Edn., Oxford university Press1999.
5. Dean A. and Voss D., *Design and Analysis of Experiments*. Springer-Verlag, 1999

ME6313D INDUSTRIAL AUTOMATION & ROBOTICS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Understand the automation concepts, architecture, strategies, functions and levels generally followed in industries

CO2: Explain various types and subsystems of industrial control systems

CO3: Understand various subsystems of robots, types, applications, history, present and future trends in robots.

CO4: Develop the kinematic, static and dynamic models of Robotic manipulators

CO5: Design appropriate trajectory for robot based applications

Module 1: (10 hours)

Introduction to automation: definition, types, merits and Criticism, architecture of industrial automation systems, manufacturing plants and operations: automation strategies, basic elements of automated system, advanced automation functions, Levels of automation.

Module 2: (12 hours)

Industrial control Systems: process and discrete manufacturing industries, continuous and Discrete Control systems: an overview of Computer process control, fundamentals of automated assembly system, actuators and sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force, strain and temperature.

Module 3: (17 hours)

Introduction to robotics: robotics system, classification of robots, robot Characteristics, kinematics for manipulator: frames and transformations, forward and inverse kinematics, DH representation,derivation of forward and Inverse kinematic equations for various types of robots, applications of robots.

Introduction to manipulator jacobian: singularity, jacobian in force domain, velocity propagation from link to link, static forces in manipulators, introduction to dynamic analysis: Lagrangian formulation, trajectory planning: joint space and cartesian space.

References:

1. John J. Craig, '*Introduction to Robotics, Mechanics and Control*', 3rd ed., Addison – Wesley, 2018.
2. Saeed B. Niku, '*Introduction to Robotics*, *Analysis, Systems and applications*', Prentice Hall India, 2002.
3. Mikell P. Groover, '*Automation, Production Systems and Computer Integrated Manufacturing*', Prentice Hall, India, 2004.
4. Mark W. Spong, and M. Vidyasagar, '*Robot Dynamics and Control*', John Wiley & Sons, 1989.
5. K. S. Fu, R. C. Gonzales, C. S. G. Lee, '*Robotics Control, Sensing, Vision and Intelligence*', McGraw Hill 1987.
6. R. P. Paul, '*Robot Manipulators Mathematics Programming', Control, The Computer Control of Robotic Manipulators*, The MIT Press, 1979.
7. Robert J. Schilling, '*Fundamentals of Robotics, Analysis and Control*', Prentice Hall of India 1996.
8. R. K. Mittal and I. J. Nagarath, '*Robotics and Control*', Tata McGraw-Hill, 2003.

9. M. Groover, and E. Zimmers, '*CAD/CAM-Computer Aided Design and Manufacturing'*, Prentice Hall of India, 2000.
10. F. G. Shinskey, '*Process Control Systems – Application, Design and Tuning'*, 4th ed., McGraw-Hill, 1996.

MS9001D RESEARCH METHODOLOGY

Pre-requisites: Nil

L	T	P	C
4	0	0	4

Total Hours : 52

Course Outcomes

CO1: Explain the basic concepts of research.
CO2: Identify various sources of information for literature review and data collection.
CO3: Understand various research designs and techniques of data analysis.
CO4: Appreciate the components of scholarly writing and evaluate its quality.
CO5: Develop an understanding of the ethical dimensions of conducting research.

Module 1: (14 hours)

Research methodology- Understanding the language of research – Concepts, constructs, operational definitions, variables, propositions, hypotheses, theories, and models - Research process- Literature review -Types of research- Problem identification andformulation - Research question – Research hypothesis - Measurement issues - Methods of data collectionTypes of data- Primary data- Scales of measurement- Sources and collection of dataObservation method- Interview method– Survey- Experiments- Secondary data-Research design- Qualitative and Quantitative Research.

Module 2: (16 hours)

Processing and analysis of data- Sampling- Steps and characteristics of sampling designSampling: concepts of Population, Sample, Sampling Frame, - Sample size and its determination - Types of sampling distributions - Sampling error - Statistics in researchDescriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Measures of relationship- Correlation and regression- Simple regression analysis- Multiple regression -Hypothesis Testing - parametric and non-parametric tests- Analysis of single factor experiments.

Module 3: (12 hours)

Reporting and presenting research - Written and oral communications -Hallmark of great scientific writing – The reading toolkit - Pre-writing considerations - Format of dissertations, research reports, and research papers – Paper title and keywords – Writing an abstract – Writing the different sections of a paper - Revising a paper - Responding to peer reviews - Reviewing research papers - Plagiarism -Conference and poster presentations - Language aspects of report writing -Verb, tense and voice in scientific writing - Errors in grammar - Sentence and paragraph constructions -Paraphrasing - Measures of research impact.

Module 4: (10 hours)

Intellectual property rights - Copyright - Patents - The codes of ethics - Avoiding the problems of biased survey -Occupational health and safety.

References:

1. Cooper, D. R. and Schindler, P. S., (2009), *Business Research Methods*, Tata McGraw Hill, 9th Edition.
2. Jackson, S.L., *Research Methods and Statistics*, Cengage Learning India Private Limited, New Delhi, 2009.
3. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., *Management Research Methodology*, Pearson Education , 2006.

4. Lebrun, J-L., *Scientific Writing: A Reader and Writer's Guide*, World Scientific Publishing Co. Pte. Ltd., Singapore, 2007.
5. MLA, MLA *Handbook for Writers of Research papers*, Seventh Edition, Affiliated EastWest Press Pvt Ltd, New Delhi, 2009.
6. Thiel, D. V., *Research Methods for Engineers*, Cambridge University Press, 2014.

CS6125D COMPUTER NETWORKING

Prerequisites: Nil

L	T	P	C
3	0	2	4

Total hours: (39 T + 26 P)

Course Outcomes

CO1: Analyze and compare new protocols in computer networks.
CO2: Evaluate performance of protocol enhancements using modern tools.
CO3: Propose new solutions to recent problems of interest in literature and compare different possible solutions

Module 1: (9 T + 7 P Hours)

Overview of computer networks, TCP/IP protocol, Application layer protocols, Software defined networking, content distribution, Web 2.0, overlay networks, P2P networks.

Module 2: (9 T + 7 P Hours)

TCP extensions for high-speed networks, Transaction-oriented applications. New options in TCP, TCP performance issues over wireless networks, SCTP, DCCP.

Module 3: (11 T + 7 P Hours)

IPv6: Why IPv6, Basic protocol, Extensions and options, Support for QoS, Security, Neighbour discovery, Auto-configuration, Routing. Changes to other protocols. Application Programming Interface for IPv6, 6bone.
IP Multicasting, Wide area multicasting, Reliable multicast. Routing layer issues, ISPs and peering, BGP, IGP, Traffic Engineering, Routing mechanisms: Queue management, Packet scheduling. MPLS, VPNs

Module 4: (10 T + 5 P Hours)

MAC protocols for high-speed LANS, MANs, Wireless LANs and mobile networks, VLAN. Fast access technologies. Gigabit Ethernet. Multimedia networking, Network management.

References

1. W. R. Stevens, *TCP/IP Illustrated*, *Vol. 1: The Protocols*, Addison Wesley, 1994.
2. G. R. Wright, *TCP/IP Illustrated, Vol. 2: The Implementation*, Addison Wesley, 1995.
3. P. Loshin, *IPv6: Theory, Protocol, and Practice,* 2/e, Morgan Kaufmann, 2003.

CS 6141D DISTRIBUTED COMPUTING

Prerequisites: Nil

L	T	P	C
3	0	2	4

Total hours: (39 T + 26 P)

Course Outcomes
CO1: Design solutions for software development problems involving asynchronous clocks.
CO2: Develop algorithms for distributed problems involving distributed mutual exclusion.
CO3: Solve problems of distributed nature where leader election issues are present.
CO3: Implement self stabilizing algorithms for failure handling in distributed applications.

Module 1 : (10 T + 7 P Hours)

Characterization of Distributed Systems, System Models, Networking and Internetworking, Interprocess communication

Module 2 : (10 T + 7 P Hours)

Logical clocks, verifying clock algorithms, Mutual Exclusion, Mutual exclusion using timestamps, tokens and Quorums.

Module 3 : (9 T + 6 P Hours)

Name Services and Domain Name System, Directory and Discovery Systems, Drinking philosophers problem, leader elections, Global state, Termination Detection

Module 4: (10 T + 6 P Hours)

Transactions and Concurrency Control, Distributed Transactions, Distributed Deadlocks, Transaction Recovery, Fault-tolerant Services, Distributed Shared Memory, Distributed consensus.

References

1. V. K. Garg, *Elements of Distributed Computing*, Wiley Interscience, 2002.
2. N. Lynch, *Distributed Algorithms*, Morgan Kaufmann Publishers Inc., 1996.
3. G. Coulouris, J. Dollimore, and T. Kindberg, *Distributed Systems Concepts And Design*, 3/e, Addison Wesley 2004.
4. A. S. Tanenbaum and V. S. Maarten, *Distributed Systems Principles and Paradigms*, Pearson Education 2004.
5. R. Chow and T. Johnson, *Distributed Operating Systems and Algorithms*, Addison Wesley 2003.
6. A. S. Tanenbaum, *Distributed Operating Systems*, Pearson Education 2005.
7. A. D. Kshemkalyani and M. Singhal, *Distributed Principles, Algorithms, and Systems,* Cambridge University Press, 2008.

CS 6191D MATHEMATICAL FOUNDATIONS OF MACHINE LEARNING

Prerequisites: Nil

L	T	P	C
4	0	0	4

Total hours: 52

Course Outcomes

CO1: Apply the fundamental concepts of Probability and Linear Algebra.
CO2: Explain and apply Multivariate analysis and Optimization Techniques.
CO3: : Use the mathematical foundations for learning Machine Learning Concepts.

Module 1: (13 T Hours)

Review of Probability Theory: Discrete and Continuous Random Variables, Joint and Marginal Distributions, Markov, Chebyshev, Jensen and Hausdorff Inequalities, Law of Large Numbers, Central Limit Theorem (No proof). Classification and Estimation: Bayes classifier, maximum likelihood and Bayesian estimation techniques.

Module 2: (13 T Hours)

Review of Linear Algebra: Vector spaces, Rank Nullity Theorem, Metric and Normed Linear Spaces, Inner product spaces, Gram Schmidt Orthogonalization, Projections and Orthogonal Projections, Introduction to Hilbert spaces. Orthogonal Decomposition algorithms: Eigen Decomposition, Singular Value Decomposition, Principal component analysis, LU, QR, Cholesky Decompositions, Least Squares Approximation

Module 3: (13 T Hours)

Review of Multivariate Analysis: Sequences and Limits, Differentiability, Level Sets and Gradients, multivariate Taylor Series. Unconstrained Optimization: Conditions for Local Minimizers of Continuously Differentiable Functions, Gradient Search, Analysis of Newton's method, Levenberg-Marquardt Modification, Quasi-Newton Methods, Rank One Correction Formula, DFP and BFGS Algorithms.

Module 4: (13 T Hours)

Constrained Optimization: Tangent and Normal Spaces, Lagrange Condition, Second-Order-Conditions, Karush-Kuhn-Tucker Condition. Convex Optimization: Lagrange and Fenchel Duality, Proximal Algorithms, ADMM Algorithm.

References

1. S. M. Ross, *Introduction to Probability and Statistics for Engineers and Scientists*, Academic Press, 2014.
2. K. Hoffman and R. Kunze, *Linear Algebra*, 2/e, Prentice Hall of India, 1990.
3. E. K. P. Chong and S. H. Zak. *An Introduction to Optimization*, 2/e, John Wiley & Sons, 2004.
4. S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004.
5. J. Eckstein, and W. Yao., *Augmented Lagrangian and Alternating Direction Methods for Convex Optimization: A Tutorial and Some Illustrative Computational Results*, RUTCOR Research Reports 32, 2012.

CS6285D INFORMATION SECURITY MANAGEMENT

Prerequisites: Nil

L	T	P	C
3	0	2	4

Total hours: (39 T + 26 P)

Course Outcomes

CO1: Review information systems in organizations and threats to these information systems.
CO2: Model security measures for organizations and examine key aspects of network security
CO3: Differentiate between notions of privacy and security and Model mechanisms for attacks and defense.
CO3: Choose the relevant building blocks of information systems for an organization with prime emphasis on security.

Module 1: (9 T + 6 P Hours)

Information as an Asset – creation and maintenance. Information systems in organizations of a global setting – Building blocks and review of current status. Threats to information systems. Information Security Management (ISM) in organizations. Information Asset Management and Risk analysis.

Module 2: (10 T + 7 P Hours)

Managing Physical and Environmental security. Perimeter security. Use of biometrics in this context. Access control models and Role based approaches for organizational hierarchy. Managing Network Security. Firewalls, VPNs and IDS. Digital certificates and CAs. Managing wireless network security.

Module 3: (10 T + 6 P Hours)

Application Security. Business Applications – choice of security architecture for third party software and turnkey software projects. Choosing the building blocks of information systems of the firm with security considerations – OS and databases, email and web servers.

Module 4: (10 T + 7 P Hours)

Disaster recovery approaches business continuity. Security models and frameworks. Security standards and compliance needs in different business domains. IT Act and other legal requirements – relevance to organizations operating in the country.

References

1. N. Godbole, *Information Systems Security: Security Management, Metrics, Frameworks and Best Practices*, John Wiley and Sons Ltd., 2009.
2. H. F. Tipton and M. K. Nozaki, *Information Security Management Handbook*, 4/e, Auerbach, 2000.
3. S. M. Furnell, S. Katsikas, J. Lopez, and A. Patel, *Securing Information and Communication Systems: Principles, Technologies and Applications*, Artech House Inc., 2008.
4. W. Michael and H. Mattord, *Management of Information Security*, Cengage Learning, 2007.

ME6612D FINITE ELEMENT METHOD AND APPLICATIONS

Pre-requisites: ME6601D Advanced Mechanics of Solids / Equivalent

L	T	P	C
3	0	0	3

Total Hours: 39

Module 1: (12 hours)

Introduction: discrete systems, assembly process, boundary conditions and solution, continuum systems; variational calculus: basics, Euler-Lagrange equation, classical applications like shortest distance problem, Brachistochrone problem, etc.; general principles in elasticity: differential and integral statements, principles of minimum potential energy and virtual work; finite element formulation: Galerkin weighted residual method, variational formulation using principles of minimum potential energy and virtual work, handling boundary conditions: essential and natural boundary conditions.

Module 2: (14 hours)

One-dimensional finite element analysis: shape functions, finite element formulation, assembly and boundary conditions, continuity requirements and order of shape functions.
Two-dimensional finite element analysis: introduction; scalar-field problems: heat transfer, torsion and potential flow problems, shape functions for triangular elements, formulation, assembly and solution; vector-field problems: stress analysis problem, rectangular elements, Lagrangian interpolation polynomials, isoparametric formulation and higher order elements, formulation, assembly and solution, introduction to three-dimensional problems.

Module 3: (13 hours)

Computational aspects: mesh generation; element shape parameters; node numbering; storage and solution schemes; finite element analysis using commercial software.
Transient analysis: finite differences and time-stepping schemes, accuracy and stability.
Nonlinear analysis: material, geometric and boundary nonlinearities, fixed-point iteration, Newton-Raphson and modified Newton-Raphson techniques, convergence and tolerance.

References:

1. J. N. Reddy, *An Introduction to the Finite Element Method*, 3rd ed. McGraw Hill Education, 2017.
2. O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu, *The Finite Element Method: Its Basis & Fundamentals*, 7th ed. Butterworth-Heinemann, 2013.
3. R. D. Cook, D. S. Malkus, M. E. Plesha, and R. J. Witt, *Concepts and Applications of Finite Element Analysis*, 4th ed. Wiley, 2001.
4. K. J. Bathe, *Finite Element Procedures*. Prentice-Hall of India, 1996.

ME6636D COMPUTER GRAPHICS

Prerequisites: NIL

L	T	P	C
3	0	0	3

Total Hours:39

Module1: (13hours)

Introduction to computer graphics: overview of computer graphics; mathematics for computer graphics; representing and interfacing with pictures; description of graphic devices; raster scan graphics; algorithms for generating line, circle and ellipse; polygon filling; fundamentals of anti-aliasing; two-dimensional and three-dimensional transformations: scaling; shearing; rotation; reflection; translation; affine and perspective geometry: orthographic; axonometric and oblique projections; perspective transformations.

Module2: (13hours)

Plane curves; non-parametric and parametric curves: space curves; representation of space curves; cubic spline; Bezier curves; B-spline curves; NURBS.

Module3: (13hours)

Surface description and generation: surface of revolution; sweep surface; linear Coons surface; Bezier surface; B-Spline surface; B-Spline surface filling.
Introduction to solid modeling; hidden lines and hidden surfaces.

As part of the course requirement, computer program oriented term projects and term papers are essential.

References:

1. D.F. Rogers and J.A. Adams, *Mathematical Elements for Computer Graphics,* 2nd ed. Tata McGraw Hill, 2009.
2. D.F. Rogers, *Procedural Elements for Computer Graphics,* 2nd ed. Tata McGraw Hill,1997.
3. D. Hearn and M.P. Baker, *Computer Graphics,*2nd ed. Prentice Hall of India,2007.
4. J.D. Foley,A.V. Dam,S.K. Feiner, and J.F. Hughes, *Computer Graphics: Principles and Practice in C,* 2nd ed. Addison-Wesley Professional,1995.
5. M.E.Mortenson, *Geometric Modeling,* 2nd ed. John Wiley & Sons,1997.

ME6626D PRODUCT DESIGN

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (12 hours)

Introduction, development processes and organizations, opportunity identification, product planning, identifying customer needs, product specifications.

Module 2: (14 hours)

Concept generation, concept selection, concept testing, product architecture, industrial design, design for environment, design for manufacturing, prototyping, robust design.

Module 3: (13 hours)

Patents and intellectual property, service design, design for sustainability, product development economics, managing projects, design of a specific product (project).

References:

1. K. T. Ulrich and S. D. Eppinger, *Product Design and Development*. McGraw-Hill, 2004.
2. G. E. Dieter, *Engineering Design*, 2nded. McGraw Hill, 1991.
3. D. G. Ullman, *The Mechanical Design Process*, 4th ed. McGraw-Hill, 2010.
4. J. E Shigley, C. R Mischeke, and R. G. Budynas, *Mechanical Engineering Design*. Tata McGraw-Hill, 2004.
5. M. G. Luchs, S. Swan, and A. Griffin, *Design Thinking*. John Wiley & Sons, 2015.
6. B. W. Niebel and A. B. Draper, *Product Design and Process Engineering*. McGraw Hill, 1974.

ME6324D INDUSTRIAL MACHINE VISION

Prerequisites: NIL

L	T	P	C
3	0	0	3

Total hours: 39

Module I: (11 hours)

Introduction: Types of inspection tasks, Structure of image processing systems, examples
Image Preprocessing: Gray Scale transformations, Image arithmetic, Linear Filters, Other Filters
Positioning: Positioning of individual object, Orientation of individual object, Robot positioning
Segmentation: Regions of interest, Thresholding, Contour Tracing, Edge based methods, Template matching

Module 2: (15 hours)

Mark Identification: Bar code identification, Character identification, Identifying pin marked digits on metal, Print quality inspection
Classification: As function approximation, Instance based classifiers, Function based classifiers, Neural network classifiers
Dimension checking: Simple Gauging, Shape checking on punched parts, injection molded parts, High accuracy gauging of threads, Calibration.

Module 3: (13 hours)

Image acquisition and illumination: Solid state sensors, Standard video cameras, other cameras, Transmission to computer, Optics, Lighting
Presence Verification: Simple presence verification, simple gauging for assembly verification, presence verification using classifiers
Object Features: Basic Features, Shape Descriptors, Gray Level Features

References:

1. Demant, *Industrial Image Processing – Visual Quality Control in Manufacturing*, 2nd ed., Springer, 2013.
2. Gonzalez, *Digital Image Processing Using MATLAB*, 2nd ed., Pearson Education, 2010.
3. Gonzalez, and Woods, *Digital Image Processing*, 3rd ed., Pearson Education, 2008.
4. Batchelor, and Whelan, *Intelligent Vision Systems for Industry*, Springer Verlag, 1997.

ME6322D SIX SIGMA

Prerequisites: NIL

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (11 hours)

Six Sigma Basics: Overview & Implementation, the DMAIC process.
Simple graphical tools: 7 QC Tools, Box Plot, Dot Plot, Stem & Leaf Plot.
Basic Statistics: Histograms to Distributions, Normal Distribution, Central Limit Theorem, Law of large numbers, t, chi-squared and F distributions.
Normal Probability Plotting on ordinary graph paper, Interpretation
Testing a new process for improvement - Variability known from past, Variability estimated from the experiment
Comparing two processes - Randomised samples, Paired samples, Comparing more than two methods simultaneously- ANOVA
Six Sigma Analyse: Experimental strategies - Deficiencies of one factor at a time experiments, Problems in analysis of past data, Necessity for randomization

Module 2: (16 hours)

Basics of Experimental Design - Terminology, Two level factorials, Estimation of effects and interactions, Yates algorithm, Unreplicated experiments - judging significance, Testing for significance in replicated experiments
Developing mathematical model equations, calculating residuals, checking whether experiment has been conducted satisfactorily
Handling non-normal response - Transformations.
Choosing the number of experiments, Testing whether linear model is satisfactory - Curvature, Handling uncontrollable factors – Blocking, Dealing with difficult to randomise factors – split plot experiments
Dealing with large number of factors, Fractional Factorial experiments, Design Resolution.
Use of DoE software

Module 3: (12 hours)

Six Sigma Metrics: DPU, DPO, DPMO, Sigma levels, Yield, First Time Yield, Overall Yield, Throughput Yield, Rolled Throughput Yield, Normalized Yield
Process Capability Indices: Cp, Cpk, Cpm, Cpkm. Dealing with non-normality through transformations, Importance of stability for capability, Effect of sample size - Confidence Intervals
Measurement System Analysis: Repeatability and Reproducibility
Every student should carry out an individual project and present the results.

References:

1. F. Breyfogle, *Implementing Six Sigma: Smarter Solutions Using Statistical Methods*, 2nd ed., John Wiley & Sons, New York, 2003.
2. M. Harry and R. Schroeder, *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, Doubleday, New York, 2000.
3. J. Lawson, and J. Erjavec, *Modern Statistics for Engineering and Quality Improvement*, Thomson Duxbury, 2000.
4. D. C. Montgomery, *Introduction to Statistical Quality Control*, 6th ed., John Wiley & Sons, Inc., New York, 2009.

ME6321D MECHATRONICS SYSTEMS

Prerequisites: NIL

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (12 hours)
Introduction to mechatronics: key elements in mechatronics, design process, types of design: traditional and mechatronics designs; advanced approaches in mechatronics; real time interfacing; elements of data acquisition system; case studies of mechatronics systems, identification of key elements of various mechatronics systems, examples.

Module 2: (12 hours)
Introduction to signals, system and controls; system representation, linearisation, time delays, measures of system performance; closed loop controller: PID controller, digital controllers, controller tuning, adaptive control; introduction to microprocessors, micro-controllers and programmable logic controllers components, PLC programming, examples.

Module 3: **(15 hours)**
Actuator and Sensors: fluid power and electrical actuators, piezoelectric actuator; sensors for position, motion, force and temperature, flow sensors-range sensors, ultrasonic sensors, fibre optic sensors, magnetostrictive transducer, selection of sensors; case studies on selection of actuators and sensors for mechatronics systems.
Advanced applications in mechatronics: sensors for condition monitoring, mechatronics control in automated manufacturing; artificial intelligence in mechatronics: fuzzy logic application in mechatronics, microsensors in mechatronics; case studies and design of mechatronics systems

References:

1. Devadas Shetty, Richard A Kolk, *Mechatronics System Design*, 6th ed., Thomson Learning, 2015
2. W. BOLTON, *Mechatronics*, 4th ed., Pearson education Asia 2004.
3. Dan Necsulescu, *Mechatronics,* Parson Education Asia 2002.
4. HMT Ltd*, Mechatronics*, 1st ed., Tata McGraw Hill, 2000
5. B.P. Singh, *Microprocessors and Microcontrollers*, 1st ed., Galgotia Pub, 1997
6. Frank D.Petruzella, *Programmable Logic Controllers*,4th ed., Tata McGraw Hill, 2010
7. Krishna Kant, *Computer Based Industrial Control*, 2nd ed., PHI, 1999

ME6147D TECHNICAL ENTREPRENEURSHIP

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (14 hours)

Introduction: Basis and challenges of entrepreneurship, Technological entrepreneurship, Innovation and entrepreneurship in technology based organizations, High Tech. Entrepreneurship, Role of technical entrepreneurs in Industrial Development, Entrepreneurial characteristics, Entrepreneurship Index and its need.
New Ventures: Concept of new ventures, Technology absorption, Appropriate technology, Networking with industries and institutions, Medium and small ventures, Product design for Rural entrepreneurs, Management concern in small and medium Enterprises.

Module 2: (14 hours)

Starting a New Technological Venture and Developing the Business: Business idea, Business plan, Marketing plan, Financial plan, Organizational plan, Financing a new venture-Sources of capital, Venture capital, Going Public.

Module 3: (11 hours)

Managing the New Technological Venture: Developing systems in new venture, managing during early operations, growth and expansion, ending the venture, Legal issues, Franchising or acquisition, Intrapreneurship, International Entrepreneurship.

References

1. B. R. Barringer, and R. D. Ireland, *Entrepreneurship: Successfully Launching New Ventures*. 5th ed., Prentice-Hall, 2016.
2. E. B. Roberts, *Entrepreneurs in High Tech- Lessons from MIT and beyond*, Oxford University Press, New York, 1991.
3. G. Vinayshil (Ed.), *Technical Entrepreneurship, Global Business Press*, New Delhi, 1992.
4. J. Timmons, *New Venture Creation: Entrepreneurship in the 1990's*, Irwin, 1998.
5. M. J. Dollinger, *Entrepreneurship: Strategies and Resources*, Irwin, Illionis, 1995.
6. R. D. Hisrich, M. P. Peters, and D. Shepherd, *Entrepreneurship*, 10th ed., Irwin Management series, McGraw-Hill Education, 2016.

ME6148D MANAGEMENT OF TECHNOLOGY AND INNOVATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (13 Hours)

Understanding Management of Technology, Key concepts – importance – issues. Process of technological change – Process versus product innovation in the generic product technology; Types of innovation, innovation technology evolution, Dominant design, Diffusion – methods of diffusion, factors governing diffusion. Expeditionary marketing

Module2: (13 Hours)

Managing technology: what is distinct, disruptive & strategic - Core Competence/Core Capability, Marquis anatomy of successful Innovation, strategic firm fit audit – Technology Market Matrix / Portfolio theory Technology Life Cycles – Technology and competition, technology acquisition; Integration of strategic planning and technology planning.Key performance factors for technology management.

Module 3: (13 Hours)

Technology Strategy: - Technology intelligence – collaborative mode, Appropriation of technology Deployment in new products; simultaneous engineering; Development in the value chain. Technology evaluation and financing – changing role of R & D, Management of manufacturing technology.

References

1. Schilling, Melissa A. *Strategic Management of Technological Innovation*, 3rd Ed. McGraw-Hill, 2010
2. Narayanan U.K., "*Managing Technology and Innovation for competitive Advantage*" Pearson Education, Asia ,2001.
3. Tarekh Khalil and Ravishankar, *Management of Technology: The key to competitiveness and wealth creation*, McGraw Hill Education; 2ndEdn. 2017
4. Burgelman et.al, *Strategic Management of Technology and Innovation* Tata Mc Graw-Hill, 2001.

MS6117D BUSINESS RESEARCH METHODS

Pre-requisite: MS6107D Business Statistics/Level 1 course on Statistics

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Total hours: 39

Course Outcomes

CO1: Develop research design for a business problem.
CO2: Compare, contrast and identify appropriate statistical tool among various alternatives to model the data.
CO3: Design the analytical model for finding business solutions.
CO4: Acquire hands on experience on the statistical software package for analyzing data.

Module 1: (13 hours)

Research methodology- Understanding the language of research – Concepts, constructs, operational definitions, variables, propositions, hypotheses, theories, and models - Research process- Literature review -Types of research- Exploratory, Explanatory, Causal, Descriptive and Explanatory research, Problem identification and formulation - Research question – Research hypothesis – Measurement issues - Methods of data collection- Types of data- Primary data- Scales of measurement: Nominal, ordinal, interval and ratio scales.

Module 2: (13 hours)

Sources and collection of data- Observation method- Interview method– Questionnaire Survey design - Experiments- Secondary data, Research design- Qualitative and Quantitative Research, Mixed research, Alternative Research designs: cross sectional, longitudinal, causal research design; Case study design versus Action research, Variables: Dependent, Independent, Moderating, Mediating, Intervening, Extraneous types, Basic analysis for research: Editing, Coding and tabulation, Sampling- Steps and characteristics of sampling design- Sampling: concepts of Population, Sample, Sampling Frame, - Sample size and its determination - Types of sampling distributions - Sampling error.

Module 3: (13 hours)

Computer packages for data analysis.-SPSS, Exploratory data analysis, Descriptive Statistics, Measures of central tendency, Measures of dispersion, Skewness, Kurtosis, Various statistical distributions, Bivariate analysis for association among variables, Correlation and regression, ANOVA versus means test and t test, Choice of bivariate methods under various distributions and scales of data, Graphical Methods, Multivariate data analysis methods, Multiple regressions, Logistic regression, Logic behind the choice of various multivariate techniques, Testing of hypothesis and Inferential statistics.

References:

1. D. R. Cooper and P.S. Schindler, *Business Research Methods*, 9th ed. Tata McGraw Hill, 2012.
2. S. L. Jackson, *Research Methods and Statistics*, Cengage, 2009.
3. K. N. Krishnaswamy, A. I. Sivakumar and M. Mathirajan, *Management Research Methodology*, Pearson, India, 2006.
4. G. A. Churchill and D. Lacobucci, *Marketing Research Methodological Foundations*, 9th ed. Cengage, 2009
5. N. Malhotra, *Marketing Research: An Applied Orientation*, 6th ed. Pearson Education, 2010.

6. W. M. K. Trochim, *Research Methods: The Concise Knowledge Base*, Atomic Dog Publishing, 2005.
7. P. Newbold, W. L. Carlson and B. Thorne, *Statistics for Business and Economics*, 8th ed., Pearson, 2013.
8. R. Levin and D. Rubin, *Statistics for Management*, 7th ed. Pearson, 2008.