M. Tech.

in

INDUSTRIAL AUTOMATION

CURRICULUM and SYLLABUS

in accordance with the guidelines of
the National Education Policy 2020 (NEP 2020) / National Credit Framework (NCrF)

(for the students admitted in the year 2024)

INSTRUMENTATION AND CONTROL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015
TAMIL NADU, INDIA

INSTITUTE VISION

To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

INSTITUTE MISSION

- To offer undergraduate, postgraduate, doctoral and modular programmes in multidisciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically

DEPARTMENT VISION

To be a world class centre of excellence in Instrumentation and Control Engineering

DEPARTMENT MISSION

- To inspire the students to realize their aspiration and potential through quality education in Instrumentation and Control Engineering.
- To enhance knowledge, create passion for learning, foster innovation and nurture talents towards serving the society and the country.
- To encourage faculty and students to keep in pace with the latest technological developments and to pursue research in those areas.
- To enable the students to engage themselves in entrepreneurship and product development for the benefit of the global community.

Programme Educational Objectives (PEOs)

M.Tech. programme in Industrial automation

1. provide fundamental and advanced knowledge in order to produce competent, innovative automation engineers.
2. use graduate engineering knowledge in Instrumentation and Control and Mechanical to design engineering systems for industrial automation.
3. promote independent and collaborative work, while demonstrate the professional and ethical responsibility.
4. promote development of intellectual property by automation engineers.
5. produce post graduate automation engineers capable of taking up research on the emerging technology and have lifelong learning.

Programme Outcome (POs)

From the Manual for Accreditation of Postgraduate Engineering Programs, NBA the POs essentially indicate what the students can do from subject-wise knowledge acquired by them during the programme.

The POs that define the professional profile of a graduate of PG Engineering Programme are

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

As per the guidelines of NEP 2020 / National Credit Framework (NCrF), the credit requirement for completing (a PG programme in Engineering) M.Tech. in Industrial Automation (IA) is 80.

The credit requirement for exit after the first year is minimum 40 credits. An exit option is provided to students after the first year with a M.Sc. (Engineering) in Industrial Automation.

Curriculum framework and Credit Distribution – M.Tech. IA programme

based on the guidelines of
National Education Policy 2020 (NEP 2020) / National Credit Framework (NCrF)

Components	**Number of Courses**	**Number of Credits**	
Programme Core (PC)	3 / Semester (6 / Year)	42	Programme Core (PC) assigned 4 credits each Programme Elective (PE) assigned 3 credits each Online Course equivalent to 3 credits Total credits: 42- PC and PE combined 6 PEs are mandatory
Programme Elective (PE)	2 / Semester (4 / Year)		
Programme Elective (PE) / Online Course in place of PE	1 / Semester (2 / Year)		
Essential Laboratory Requirement (LR)	3 / Year	6	2 credits / LR
Internship / Industrial Training / Academic Attachment (I/A)	1	2	To be completed after the first year during the summer term
• Open Elective (OE) • Online Courses (OC) • Microcredit Courses (MC) (Online / Offline)	2 / 3 / 4	6	Online Courses (OC) to be completed within 1st and 3rd semesters. 3 credits through Online Courses can also be earned in terms of Microcredits
Project Work (Phase – I)	1	12	-
Project Work (Phase – II)	1	12	-
Total	20	**80**	

CURRICULUM

SEMESTER I (July session)

Code	Course of Study	Credit
MA623	Applied Mathematics	4
IC601	Measurements in Manufacturing and Process Industries	4
IC603	Industrial Automation Systems	4
IC6XX	Programme Elective I	3
IC6XX	Programme Elective II	3
IC6XX / OC6XX	Program Elective III / Online (NPTEL/Coursera)	3
IC605	Instrumentation and Measurement Laboratory	2
IC607	Process Control and Automation Laboratory	2
		25

SEMESTER II (January session)

Code	Course of Study	Credit
IC602	Industrial and Data Communications	4
IC604	Electric Drives and Control	4
IC606	Robotics in Industrial Automation	4
IC6XX	Programme Elective IV	3
IC6XX	Programme Elective V	3
IC6XX / OC6XX	Program Elective VI / Online (NPTEL/Coursera)	3
IC608	AI and Robotics Laboratory	2
		23

SEMESTER III (July session)

Code	Course of Study	Credit
IC611	Summer Term-Internship / Industrial Training / Academic Attachment (6 weeks to 8 weeks)	2
IC609	Project Work (Phase I)	12

SEMESTER IV (January session)

Code	Course of Study	Credit
IC610	Project Work (Phase II)	12

OPEN ELECTIVE /ONLINE COURSE (OC) and MICROCREDIT COURSE (MC)

(to be completed within 1st and 3rd semesters)

Code	Course of Study	Credit
OC6XX / MC6XX	ONLINE COURSE (OC) (1/2/3 credit) MICROCREDIT COURSE (MC) (1 credit)	6

PROGRAMME ELECTIVES (PE)

Sl. No.	Code	Course of Study	Credit
1.	IC612	Artificial Intelligence in Industrial Automation	3
2.	IC613	Modelling, Simulation and Analysis of Manufacturing Systems	3
3.	IC614	Industrial Internet of Things	3
4.	IC615	Embedded Systems	3
5.	IC616	Computer Vision and Image Processing	3
6.	IC617	Intelligent Transportation Systems	3
7.	IC618	Wireless Sensor Networks	3
8.	IC619	Fluid Power Systems	3
9.	IC620	Augmented Reality	3
10.	IC621	Advanced Control Systems	3
11.	IC622	Networked Control Systems	3
12.	IC623	System Identification	3
13.	IC624	Cyber Security in Industrial Automation	3
14.	IC625	Building and Infrastructure Systems and Automation	3
15.	IC626	Rapid Prototyping	3
16.	IC627	Predictive Analytics	3
17.	IC628	Optimization Techniques	3
18.	IC629	Advanced Sensor Interfacing Circuits	3
19.	IC630	Automation in Financial Technology	3
20.	IC631	Nonlinear Control	3
21.	IC632	Robot Dynamics and Control	3
22.	IC633	Condition Monitoring: Industrial Practices	3
23.	IC634	Modern Optimization Techniques and Algorithms	3

OPEN ELECTIVES (OE)

Sl. No.	Code	Course of Study	Credit
1.	OE612	Artificial Intelligence in Industrial Automation	3
2.	OE613	Modelling, Simulation and Analysis of Manufacturing Systems	3
3.	OE614	Industrial Internet of Things	3
4.	OE615	Embedded Systems	3
5.	OE616	Computer Vision and Image Processing	3
6.	OE617	Intelligent Transportation Systems	3
7.	OE618	Wireless Sensor Networks	3
8.	OE619	Fluid Power Systems	3
9.	OE620	Augmented Reality	3
10.	OE621	Advanced Control Systems	3
11.	OE622	Networked Control Systems	3
12.	OE623	System Identification	3
13.	OE624	Cyber Security in Industrial Automation	3
14.	OE625	Building and Infrastructure Systems and Automation	3
15.	OE626	Rapid Prototyping	3
16.	OE627	Predictive Analytics	3
17.	OE628	Optimization Techniques	3
18.	OE629	Advanced Sensor Interfacing Circuits	3
19.	OE630	Automation in Financial Technology	3
20.	OE631	Nonlinear Control	3
21.	OE632	Robot Dynamics and Control	3
22.	OE633	Condition Monitoring: Industrial Practices	3
23.	OE634	Modern Optimization Techniques and Algorithms	3

ONLINE COURSES (OC)
(to be completed within 1st and 3rd semesters)

All the courses (eligible for M.Tech. programme) offered online in SWAYAM portal and Coursera during the respective session can be considered for the list of online courses (OC)

Students can also opt for online courses of 2 credit (8 weeks / 24 hours)

Sl. No.	Code	Course of Study	Credit
1.	OC6XX	Fundamentals of Micro and Nanofabrication	3
2.	OC6XX	Distributed Optimization and Machine Learning	3
3.	OC6XX	Practical Cyber Security for Cyber Security Practitioners	3
4.	OC6XX	Social Innovation in Industry 4.0	3
5.	OC6XX	Industrial Robotics: Theories for Implementation	3
6.	OC6XX	Automation in Manufacturing	3
7.	OC6XX	Fundamentals of Artificial Intelligence	3

MICROCREDIT COURSES (MC)

Students can opt 3 courses of {1 credit (4 weeks / 12 hours); 2 credit (8 weeks / 24 hours)} each as microcredits instead of one OE/OC (3 - credit)

Sl. No.	Code	Course of Study	Credit
1.	MC6XX	Equipment Design: Mechanical Aspects	1
2.	MC6XX	Product Design and Development	1
3.	MC6XX	Drone Technology	1
4.	MC6XX	Automobile Technology	1
5.	MC6XX	Python Programming	1

Course Code	**:**	**MA623**
Course Title	**:**	**Applied Mathematics**
Type of Course	**:**	PC
Credits / Contact Hours	**:**	4 / 56 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn the concepts of probability and statistics to industrial automation engineering problems
CLO2	Familiar with reliability engineering theory in determining the reliability of the systems.
CLO3	To predict the relationship between parameters through correlation and regression analysis
CLO4	Compute the reliability of the systems

Course Content

Random variable – Two-dimensional random variables – Standard probability distributions – Binomial, Poisson and Normal distributions - Moment generating function.

Special distributions – Uniform, Geometric, Exponential, Gamma, Weibull and Beta distributions –Mean, Variance, Raw moments from moment generating functions of respective distributions.

Sampling distributions – Confidence interval estimation of population parameters – Testing of hypotheses – Large sample tests for mean and proportion – t-test, F-test and Chi-square test. Case studies pertaining to engineering.

Curve fitting - Method of least squares - Regression and correlation – Rank correlation – Multiple and partial correlation – Analysis of variance - One-Way and two-way classifications Case studies pertaining to engineering.

Introduction to Multivariate statistical analysis – Multiple linear regression-Multiple logistic regression – Multivariate analysis of variance (MANOVA) – Introduction to Factor analysis, Cluster analysis, Principal components analysis (PCA).

Text Books

1.	*Gupta S.C. and Kapoor V.K., "Fundamentals of Mathematical Statistics", 11th Edition Sultan Chand, New Delhi, 2018.*
2.	*Trivedi K.S., "Probability and Statistics with Reliability and Queuing and Computer Science Applications", 2nd Edition, Wiley, 2008.*

References

1.	*Spiegel, Murray, "Probability and Statistics", Schaum's series*, McGraw Hill, 2017.
2.	*Spiegel, Murray R., "Statistics", Schaum's series, 2008.*
3.	*Bowker and Liberman, "Engineering Statistics", 2nd Edition, Prentice*-Hall, 1972.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply standard and special probability distributions to automation engineering problems.
CO2	Indicate data pictorially and numerically and analyze it.
CO3	Employ sampling distributions in testing various hypotheses.
CO4	Use t-test, F-test and Chi-square test in determining the validity of data.

Course Code	**:**	**IC601**
Course Title	**:**	**Measurements in Manufacturing and Process Industries**
Type of Course	**:**	PC
Credits / Contact Hours	**:**	4 / 56 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the importance of measurements in manufacturing and process industries
CLO2	To expose the students to various measurement techniques used for the measurement ofphysical variables in manufacturing industries
CLO3	To expose the students to various measurement techniques used for the measurement of physical variables in process industries
CLO4	To make the students knowledgeable in the design, installation and troubleshooting of theinstruments used in manufacturing and process instruments

Course Content

Transducers: Resistance, capacitance, inductance type, piezoelectric and photoelectric transducers- signal conditioning circuits, and its static and dynamic characteristics and its applications.

Calibration and ISA standards. Proximity Sensors: Inductive, Capacity, Magnetic, Ultrasonic, IR, Light detection and ranging (Lidar) sensors, applications of proximity sensors.

Review of temperature measuring instruments. Transmitters: two wire and four wire, open loop and closed loop transmitters, smart, intelligent and wireless transmitters, transmitter design using analog circuits and ICs.

Flow measurement: Differential pressure and variable area flow meters, Electromagnetic flow meters. Hot wire anemometer, laser Doppler anemometer, ultrasonic and measurement of mass flow rate. Level measurement - Differential pressure level detectors, Capacitance level sensor, Ultrasoniclevel detectors and Radar level transmitters and gauges.

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

Application of sensors in automation: Assembly shop in automobile manufacturing, Autonomous vehicle, oil and gas pipeline monitoring, water distribution system, intelligent transportation systems, monitoring of food.

Quality and safety, sorting, counting and bottle filling system, construction and management,building and home, rail, and filling of gas cylinders.

Text Books

1.	*Ernest. O. Doebelin and Dhanesh.N.Manik, "Measurement Systems, McGraw Hill Education, 6th Edition, 2011.*
2.	*Thomas G. Beckwith, Roy D. Marangoni, Lienhard, "Mechanical Measurements", Pearson Education India, 6th Edition, 2013*
3.	*Patranabis D, "Principles of Industrial Instrumentation", Tata McGraw Hill, 3rd Edition, 2010.*

References

1.	*B.G.Liptak, "Process Measurement and Analysis", CRC Press, 4th Edition, 2003.*
2.	*B.E.Noltingk, "Instrumentation Reference Book", Butterworth Heinemann, 2nd Edition,1995.*
3.	*Douglas M. Considine, "Process / Industrial Instruments and Controls Handbook", McGraw Hill, Singapore, 5th Edition, 1999.*
4.	*Andrew W.G, "Applied Instrumentation in Process Industries – A survey", Vol I andVol II,Gulf Publishing Company, Houston, 2001*
5.	*Spitzer D. W., "Industrial Flow measurement", ISA press, 3rd Edition, 2005.*
6.	*Tony. R. Kuphaldt, "Lessons in Industrial Instrumentation", Version 2.02, April 2014.*
7.	*Lawrence D. Goettsche, "Maintenance of Instruments and Systems", International Society of Automation, 2nd Edition, 2005.*
8.	*Norman A. Anderson, "Instrumentation for Process Measurement and Control", CRCGroup, Taylor and Francis Group, 3rd Edition, 2010.*
9.	*James W. Dally, William F. Riley, Kenneth G. McConnell "Instrumentation for Engineering Measurements", Wiley India Private Limited, 2nd Edition, 2010.*
10.	*Alessandro Brunelli, "Calibration Handbook of Measuring Instruments", ISA, 2017*
11.	*Mohit Pandey, Shreyansh Tatiya, Shantanu Bhattacharya, Shailendra Singh, "Sensorsfor Automotive and Aerospace Applications", Springer Singapore, 2019*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Study the characteristics and specification of instruments
CO2	Understand the sensors and transducers used in manufacturing industries like displacement,velocity, acceleration, force, torque and load.
CO3	Gain knowledge of different temperature, pressure, flow and level measurement techniquesused in process industries.
CO4	Grasp the industrial safety aspects.

Course Code	**:**	**IC603**
Course Title	**:**	**Industrial Automation Systems**
Type of Course	**:**	PC
Credits / Contact Hours	**:**	4 / 56 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To present the importance of automation in manufacturing and process industries.
CLO2	To impart the role of PLC in industrial automation
CLO3	To expose the various automation techniques employed in process control
CLO4	To impart knowledge on different communication protocols used in process automation

Course Content

Automation in Manufacturing and Process Industries:
Introduction: Automation in manufacturing system, Principles and strategies of automation, Basic elements of an automated system, Advanced automation functions, Levels of automations, Various Industrial Revolutions, Digitalization and the Networked Economy, Drivers, Enablers, Compelling Forces and Challenges for Industry 4.0.

Technologies enabling Industry 4.0: Introduction and overview of Internet of Things, cloud computing, cyber-physical systems.
Automated flow lines and transfer mechanisms: Analysis of transfer lines without storage, automated flow lines with storage buffers
Introduction to Smart Manufacturing: smart devices and products, smart logistics, smart cities, predictive analytics

Programmable Logic Controller (PLC): Introduction to PLC, History of PLC, Architecture of PLC, CPU IO Modules Power Supply and Communications, Input and Output Devices, Need of PLC for Industrial Automation, Types of PLC Models.
Introduction to PLC Programming: Types of Programming Languages, Ladder logic diagram, Examine On/OFF, timer, counter, data manipulation and other higher-level programming instruction with case studies.

Overview of material handling systems: Types of material handling equipment, Design of the system, Conveyor system, Automated guided vehicle system.
Automated Manufacturing Systems: Components, Classification and overview of manufacturing systems, Cellular manufacturing, Flexible manufacturing system (FMS).

SCADA Systems: Introduction, definition and history of SCADA, typical SCADA System Architecture, Communication requirements, Desirable properties of SCADA system, Features, advantages, disadvantages and applications of SCADA.

SCADA Architecture: First Generation-Monolithic, Second Generation-Distributed, Third Generation-Networked Architecture, SCADA systems in operation and case studies.
Distributed control systems (DCS): Introduction - Local Control Unit (LCU) architecture, LCU Process Interfacing Issues, Block diagram and Overview of different LCU security design approaches, Networking of DCS. Information gathering, Real-time analysis of data stream from DCS, Historian, Integration of business inputs with process data, Leveraging remote terminal unit (RTU).

Process Safety Automation: Levels of process safety through use of PLCs, Integrating Process safety PLC and DCS, Application of international standards in process safety control.

Text Books

1.	*M.P.Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing, 5th edition, Pearson, 2024*
2.	*John W. Webb and Ronald A. Reis, "Programmable Logic Controllers: Principles and Applications", 5th Edition, Prentice Hall Inc., New Jersey, 2003.*
3.	*Krishna Kant, "Computer - Based Industrial Control", 2nd Edition, Prentice Hall, New Delhi, 2011.*
4.	*Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw- Hill, New York, 2016.*
5.	*Ronald L Krutz, "Securing SCADA System", First Edition, Wiley Publication, 2005*

References

1.	*Curtis D. Johnson, "Process Control Instrumentation Technology", 8th Edition, Pearson New International, 2013.*
2.	*Lukas M.P, "Distributed Control Systems", Van Nostrand Reinhold Co., New York, 1986.*
3.	*N. Viswanandham, Y. Narahari, "Performance Modeling of Automated Manufacturing Systems", 1st Edition, 2009.*
4.	*https://nptel.ac.in/syllabus/108108098/*
5.	*Smith Carlos and Corripio, "Principles and Practice of Automatic Process Control",3rd Edition, John Wiley and Sons, 2006*

Course Outcomes (CO)

At the end of the course student will be

CO1	Familiar with various automation technologies used in manufacturing and process industries.
CO2	Able to apply various programming techniques for manufacturing industry automation.
CO3	Understand various automation techniques such as DCS and SCADA for process industry automation.
CO4	Familiar with various process safety automation and I4 standards.

Course Code	**:**	**IC607**
Course Title	**:**	**Process Control and Automation Laboratory**
Type of Course	**:**	Laboratory
Credits / Contact Hours	**:**	2 / 28 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Impart knowledge in transmitter design.
CLO2	Exposure to different PLC programming languages.
CLO3	Able to provide adequate knowledge in SCADA and DCS.
CLO4	Study of HART and Field bus protocol.

List of Experiments

1. Design and development of two-wire temperature Transmitter.
2. Design and development of IoT based transmitter.
3. Design and implementation of feedback and cascade control schemes on the Experimental set up.
4. Design and implementation of feed forward and ratio control schemes on the Experimental set up.
5. Development of combinational and sequential logic application using minimum PLC languages.
6. Development of Ladder logic Program for control of processes.
7. Development of SCADA for a control of processes.
8. Study of HART and Field bus protocol.
9. PandI diagram development using simulation software for complex processes.
10. Study of Distributed Control System and different instruction sets.
11. Development of Cascade, ratio and feedback controller using DCS simulation software.
12. Development of HMI and annunciator circuits using DCS simulation software.

Course Outcomes (CO)

At the end of the course student will

CO1	Gain confidence in development of conventional/ wireless IoT based transmitter suitedfor real time processes.
CO2	Get exposure in design of different controller suitable for real time processes.
CO3	Acquire adequate programming skills using PLC, DCS and SCADA.
CO4	Gain knowledge on Ladder Logic programming.

Course Code	**:**	**IC605**
Course Title	**:**	**Instrumentation and Measurement Laboratory**
Type of Course	**:**	Laboratory
Credits / Contact Hours	**:**	2 / 28 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Impart knowledge in use of various sensors in automation
CLO2	Exposure to the design of different signal conditioning elements required for automation
CLO3	Able to suggest sensing technique required for various industry automation problems
CLO4	Able to design and demonstrate simple automation systems.

List of Experiments

1. Frequency Response of Piezoelectric transducer (Improving the low frequency response by suitable signal conditioning circuits)
2. Design of closed loop sensor with piezoelectric transducer
3. Design of energy harvester using piezoelectric material
4. Design of sensing circuit/ element for Automation using inductive transducer (LVDT)
5. Design of sensing and actuation element for automation using Eddy current transducer.
6. Design of sensing and actuation unit for Automation using Hall effect transducer.
7. Design of counting unit for packaging automation by considering suitable sensor.
8. Design of level sensing for automation of bottling plant using optical/capacitor sensor.
9. Design of sensing and actuation unit for Automation using Light detection and ranging (Lidar) sensors.
10. Measurement of level using four different sensors
11. Measurement of flow using three different flowmeters
12. Design and test a conveyor belt-based automation for bottling / packaging unit with identifying required sensor, Actuator and mechanical system.
13. Design and testing of Automated weighing unit using Resistive transducer.
14. For any one domestic appliance like Dishwasher or Washing machine, study of the complete automation by dismantling and identifying the component used.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the role of sensors in industrial automation system design.
CO2	Design instrumentation system for the measurement of various parameters.
CO3	Understand various design concepts required for implementing automation
CO4	Develop skills required for the design of automation system.

Course Code	**:**	**IC602**
Course Title	**:**	**Industrial and Data Communications**
Type of Course	**:**	PC
Credits / Contact Hours	**:**	4 / 56 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to Communication systems emerged in the field of industrial automation.
CLO2	To learn the protocols used for data communication.
CLO3	to test, build, wire and troubleshoot the different types of industrial data communicationcircuits used for instrumentation
CLO4	To expose the students to more advanced, precise and complex instrumentations whichare being employed in the automation industry

Course Content

Interface: Introduction, Principles of interface, serial interface and its standards, Parallel interfaces and buses, OSI Standard – TCP/IP protocol.

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

Instrumentation network design and upgrade: Instrumentation design goals, cost optimal and accurate sensor networks, Global system architectures, advantages and limitations of open networks, HART network, Foundation fieldbus network, control area network (CAN) and MQTT protocol, Open Platform Communications Unified Architecture (OPC-UA).

HART and MODBUS: Concept of Highway Addressable Remote Transducer (HART), HART and smart Instrumentation, HART protocol, HART Physical layer, HART Data link layer, HART benefits, Troubleshooting of HART, Overview of Modbus protocol, Modbus protocol structure.

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

CAN Bus: Introduction to CAN, messages, physical layers, connectors, Bit timing, Error handling,higher layer protocols, automotive applications.

MQTT: Introduction, public and subscribe basics, client, broker and connection establishment, Quality of Service, MQTT over web-sockets. Applications of MQTT: M2M communication, IoT.

Text Books

1.	*B.G. Liptak, "Process software and digital networks", 3rd Edition, CRC press, Florida,2003.*
2.	*Michael A. Miller, "Introduction to Data and Network Communication", 1st edition DelmarCengage Learning, 1992.*
3.	*Forouzen, Data Communication and Networking, second Edition, MHE, 2017*

References

1.	*Stallings Williams, "Data and Computer Communication", Fourth Edition, PHI Learning,New Delhi, 1994.*
2.	*Tannebaum Andrew S, Wetherall David J, "Computer Networks Pearson", 5th Edition,Prentice Hall, USA, 2011.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the concepts required for building industrial systems.
CO2	Explain various methods and protocols used for data communication.
CO3	Troubleshoot problems in hardware/software employed in data communication circuit.
CO4	Install various types of network devices and another network hardware for field andProfiBUS.

Course Code	**:**	**IC604**
Course Title	**:**	**Electric Drives and Control**
Type of Course	**:**	PC
Credits / Contact Hours	**:**	4 / 56 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce basic concepts of load and drive interaction, speed control concepts of ac and dc drives, speed reversal, regenerative braking aspects
CLO2	To introduce to the students on the concept of employing power convertors for the design of electric drives
CLO3	To impart knowledge on the analysis of electric drive system dynamics.
CLO4	To impart knowledge on the design methodology and development of control methods for electric drive systems.

Course Content

Components of electrical drives system – electric machines, power converter, controllers – dynamics of electric drive – types of load – shaft-load coupling systems – four quadrant operationof a motor – stability of power electronic drive.

DC motor drives – conventional methods of speed control, single phase and three-phase converterfed DC motor drive. Four-quadrant operation.

Chopper fed drives, input filter design. Braking and speed reversal of DC motor drives using choppers, multiphase choppers. PV fed DC drives.

Induction motor drives – conventional methods of speed control – solid-state controllers for stator voltage control – soft starting of induction motors, Rotor side speed control of wound rotor induction motors. Voltage source and Current source inverter fed induction motor drives – d-q axismodeling and vector control.

Synchronous motor drives – speed control of synchronous motors – field-oriented control – load commutated inverter drives – switched reluctance motor drives and permanent magnet motor drives. Sensor less speed control. Case studies on drives and applications.

Text Books

1.	*Richard Crowder, "Electric Drives and Electromechanical Systems", 2nd Edition, Elsevier, 2019*
2.	*Ion Boldea, S. A. Nasar," Electrical Drives", 3rd Edition, CRC Press - 2016.*
3.	*R. Krishnan, "Electrical Motor Drives", PHI - 2001.*
4.	*G. K. Dubey, "Fundamentals of Electrical Drives", 2nd Edition, Narosa -2009.*
5.	*M. A. El-Sharkawi, "Fundamentals of Electrical Drives", Cengage Learning, 2nd edition, 2000.*

References

1.	*Vedam Subrahmaniam," Electric Drives", 2nd Edition, TMH - 2017.*
2.	*Ramu Krishnan," Permanent Magnet Synchronous and Brushless DC Motor Drives", CRC Press, 2017.*
3.	*W. Leohnard, "Control of Electric Drives", 3rd Edition, Springer - 2001.*
4.	*Bimal K Bose, "Modern Power Electronics and AC Drives", Prentice Hall, 1st edition, 2002.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Design suitable power electronic circuit for an electric drive system and analyze its steady state stability.
CO2	Select appropriate control method for the electric drives.
CO3	Select a suitable electric drive for a particular industrial application.
CO4	Design and implement a prototype drive system.

Course Code	:	**IC606**
Course Title	:	**Robotics in Industrial Automation**
Type of Course	:	PC
Credits / Contact Hours	:	4 / 56 hours
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the basic concepts, types and parts of Robots.
CLO2	To understand the assignment of reference frames to Robots and their Transformations.
CLO3	To study the Dynamic Modeling of Robots and design Controllers for trajectory tracking.
CLO4	To familiarize about the various Automation principles with applications of Robots in industries.

Course Content

Introduction: Fundamentals of Robotics, Links, Joints, End Effectors, Actuators.

Spatial Description: Position and Orientation, Degrees-of-Freedom, Reference Frames Assignment, Homogeneous Transformation, Denavit-Hartenberg (D-H) Parameters.

Kinematic Analysis: Direct Kinematics, Inverse Kinematics, Linear Velocities, Angular Velocities, Jacobian, Singularity, Static Force Analysis.

Dynamic Analysis: Lagrangian Formulation of Manipulator Dynamics, Structure of Manipulator Dynamic Equations, Manipulator Dynamics in Cartesian Space.

Controller Design: Feedback Control System, Stabilization and Tracking Problems, Control of Second-Order Systems, Design of Linear Controller for Trajectory Tracking.

Automation: Automation Principles and Strategies, Fixed Automation, Automated Flow Lines, Methods of work part transport, Transfer Mechanisms, Continuous Transfer, Intermittent Transfer, Indexing Mechanisms, Material Handling Systems, Automated Guided Vehicle Systems, Automated Storage and Retrieval Systems (ASRS), Automated Inspection Principles and Methods, Sensor Technologies for Automated Inspection, Machine Vision.

Applications: Applications of Robots in Welding, Spray Painting, Assembly operation, cleaning, underwater applications, Micro Robotics, Bio Robotics, Mobile Robotics, Aerial Robotics.

Text Books

1.	*A. Ghoshal, "Robotics: Fundamental Concepts and Analysis", Oxford University Press, 2010*
2.	*Richard D Klafter, Thomas Achmielewski and Michael Negin," Robotics Engineering: AnIntegrated Approach" Parentice Hall India, New Delhi,2001*
3.	*J. J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education, 2022*
4.	*Mikell P Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing", Pearson Education, 2016.*

References

1.	*S. J. Derby, "Design of Automatic Machinery", CRC Press, 2004*
2.	*S. R. Deb and S. Deb, "Robotic Technology and Flexible Automation", Tata McGraw Hill, 2010*
3.	*R. M. Murray, Z. Li, and S. S. Sastry, "A Mathematical Introduction to Robotic Manipulation", CRC Press, 2017*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the basic concepts of working of robot.
CO2	Apply their knowledge in handling the materials
CO3	Analyze instrumentation systems for inspection and testing
CO4	Use robots in different applications

Course Code	**:**	**IC608**
Course Title	**:**	**AI and Robotics Laboratory**
Type of Course	**:**	Laboratory
Credits / Contact Hours	**:**	2 / 28 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Impart knowledge on Robot programming and Robot operation control
CLO2	Expose students to SCADA and various data communication protocols
CLO3	To learn the ML and DL models.
CLO4	To implement the DL models for real time data.

List of Experiments

1. Operator control of Robot and jog the Robot.
2. Robot Programming: "In-air" program (Point to Point motion).
3. Robot programming: Fillet joint weld, circular joint weld and Linear joint weld.
4. Actuation of Pneumatic circuit for Rotary Pusher Module and interface with Programmable Logic Control.
5. Actuation of Single Acting Cylinder using a two-way Pressure Valve using Flow Control Valve.
6. Trouble Shooting the Sensor and Actuator using MAPS-6S Multistation.
7. Simulation of movements in HMI and SCADA (using Analog data).
8. Signal processing (A/D and D/A) using SCALEX and NORMX Blocks.
9. Execute an Instruction from the cloud to stop the machine operation.
10. Integration of MAPS-6S Automation Kit using Profinet Protocol.
11. Configure and Visualize the Thing data using OPC-UA Protocol.
12. Configure and Visualize the Thing data using Modbus adapter.
13. Algorithm for Data pre-processing.
14. Development of regression algorithms for the given data.
15. Implementation of classification algorithms.
16. Development of Deep network models.
17. Application and case studies related to manufacturing industries.
18. Application and case studies related to process industries.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply standard and special probability distributions to automation engineering problems.
CO2	Indicate data pictorially and numerically and analyze it.
CO3	Employ sampling distributions in testing various hypotheses.
CO4	Use t-test, F-test and Chi-square test in determining the validity of data.

Course Code	**:**	**IC612**
Course Title	**:**	**Artificial Intelligence in Industrial Automation**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To identify potential areas for automation and justify need for automation
CLO2	Study the concepts of Artificial Intelligence.
CLO3	Learn the methods of solving problems using Artificial Intelligence.
CLO4	Apply the concepts of AI to attain industrial automation

Course Content

Introduction to Artificial Intelligence – Introduction - Foundations of AI- History of AI Intelligent agents: Agents and Environment- Reactive agent- deliberative- goal-driven, utility driven and learning agents.

Machine learning: Supervised learning– Classification methods-Nearest neighbor- Decision trees- Linear discriminant Analysis - Logistic regression- Support Vector Machines Unsupervised learning: Clustering- Clustering Methods-Partitioned based Clustering - K-means- K-medoids; Hierarchical Clustering - Agglomerative- Divisive- Distance measures.

Structure and function of a single neuron; Artificial Neural Networks (ANN); Single-layer networks; Perceptron-Linear separability, Training algorithm, Limitations; Multi-layer networks-Architecture, Back Propagation Algorithm (BTA) training algorithms; Recurrent Networks; Feed-forward networks; Radial-Basis-Function (RBF) networks.

Typical applications of ANNs: Classification, Function Approximation, Forecasting, Control, Optimization-Reinforcement learning, Basics of Deep Learning-CNN-LSTM.

Applications of Artificial Intelligence- ML and DL models in Manufacturing-Health Monitoring-Predictive Maintenance.

Text Books

1.	*Rich and Knight, "Artificial Intelligence", 3rd Edition, Tata McGraw Hill, 2014.*
2.	*Ethem Alpaydin, "Machine Learning the New AI", MIT press, 2016.*
3.	*Ian Good Fellow, Yoshua Bengio, Aaron Courville, DEEP LEARNING - The MIT Press (18 November 2016).*

References

1.	*Stuart Russell and Peter Norvig, "Artificial Intelligence - A Modern Approach", 4th Edition, Pearson, 2020.*
2.	*Richard E. Neapolitan, and Xia Jiang, "Artificial Intelligence -With an Introduction to Machine Learning", 2nd Edition, CRC press, 2018.*
3.	*Anuradha Srinivasaraghavan, Vincy Joseph "Machine Learning", Wiley, 2019*
4.	*Wolfgang Ertel," Introduction to Artificial Intelligence", Second Edition, Springer, 2017.*
5.	*Rajiv Chopra, "Deep Learning", 1st edition, Khanna Publishing House, 2018.*
6.	*Deepak Khemani, "A First Course in Artificial Intelligence", McGraw Hill Education, 2013.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand basic AI algorithms.
CO2	Identify appropriate AI methods to solve a given problem.
CO3	Acquire knowledge about AI/ ML/DL techniques in Industrial automation.
CO4	Understand the levels of automation.

Course Code	**:**	**IC613**
Course Title	**:**	**Modelling Simulation and Analysis of Manufacturing Systems**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand a model and document a problem.
CLO2	Study different techniques to generate random variate.
CLO3	Use the different simulation language to model and analyze problems found in industrial automation.
CLO4	To design and analyze a simulation experiment.

Course Content

Principles of Modeling and Simulation -Basic Simulation Modeling, appropriate simulation, not appropriate simulation, Advantages and disadvantages and pit falls of simulation, Monte - Carlo Simulation, Areas of applications, Discrete and Continuous Systems, Modeling of a system, Types of models, Discrete event simulation.

Modeling Approaches - Modeling complex systems, List processing in simulation, Simple simulation language, Single server queuing systems, Time shared computer model, Multiteller banking with jockeying, Job shop model.

Random Number Generation -Basic probability and statistics- random variables and their properties, Properties of random numbers, generation of pseudo random numbers, Techniques for generating random numbers, Various tests for random numbers-frequency test, and test for autocorrelation.

Random Variate Generation - Introduction, Different techniques to generate random variate: Inverse transform technique, Normal, Uniform, Weibull, Direct transformation technique for normal and log normal distribution, Convolution method and acceptance rejection techniques-Poisson distribution, Output Data Analysis for a single system -Types of simulation with respect to output analysis, transient and steady state behavior of a stochastic process.

Statistical Techniques - Comparison of two-system design, Comparison of several system design – Bonferroni approaches to multiple comparisons for selecting best fit, for screening, Variance reduction techniques such as simple linear regression, multiple linear regression.

Simulation Studies -Simulation of inventory problems, Discrete event simulation problems, Experimental design and optimization, 2k factorial designs, Simulation of manufacturing systems.

Text Books

1.	*Jerry Banks, John Carson, Barry L. Nelson, David Nicol, "Discrete - Event Systems Simulation", 4th edition, Prentice Hall, 2011.*
2.	*Averill Law and David M. Kelton, "Simulation, Modelling and Analysis", TMH, 4th Edition, 2007.*

References

1.	*Guy L. Curry, Richard M. Feldman, "Manufacturing Systems Modeling and Analysis", Second Edition, Springer-Verlag Berlin Heidelberg, 2011.*
2.	*Richard A. Johnson, "Probability and Statistics for Engineers", 8th edition, Pearson, 2010.*
3.	*Geoffrey Gordon, "System Simulation", Prentice Hall, 2nd edition, 2009.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Analyze, model, and select appropriate input distributions and to explain simulation time advance mechanisms
CO2	Understand types of simulation with respect to output analysis
CO3	Apply appropriate simulation statistical output techniques.
CO4	Develop and apply appropriate random number and random variable generation techniques.

Course Code	**:**	**IC614**
Course Title	**:**	**Industrial Internet of Things**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide a good understanding of Internet of Things (IoT) and it's envisioned deployment domains.
CLO2	To provide an understanding of smart sensors/actuators with their internet connectivity for experimentation and designing systems.
CLO3	To provide an overview about the various protocol standards deployed in the Internet of Things (IoT) domain and to make informed choices.
CLO4	To impart knowledge in the design and development of IoT systems with enablementensuring security and assimilated privacy.

Course Content

Introduction to Internet of Things - Overview of Internet of Things- the Edge, Cloud and the Application Development, Anatomy of the Thing, Industrial Internet of Things (IIoT - Industry 4.0), Quality Assurance, Predictive Maintenance, Real Time Diagnostics, Design and Development for IoT, Understanding System Design for IoT, Design Model for IoT.

System Design of Connected Devices - Embedded Devices, Embedded Hardware, Connected Sensors and Actuators, Controllers, Battery Life Conservation and designing with Energy Efficient Devices, SoCs, CC3200, Architecture, CC3200 Launchpad for Rapid Internet Connectivity with Cloud Service Providers.

Understanding Internet Protocols - Simplified OSI Model, Network Topologies, Standards, Types of Internet Networking – Ethernet, WiFi, Local Networking, Bluetooth, Bluetooth Low Energy (BLE), Zigbee,6LoWPAN, Sub 1 GHz, RFID, NFC, Proprietary Protocols, SimpliciTI, Networking Design – Push, Pull and Polling, Network APIs.

System Design Perspective for IoT – Products vs Services, Value Propositions for IoT, Services in IoT, Design views of Good Products, Understanding Context, IoT Specific Challenges and Opportunities.

Advances Design Concepts for IoT – Software UX Design Considerations, Machine Learning

and Predictive Analysis, Interactions, Interusability and Interoperability considerations, Understanding Security in IoT Design, Design requirements of IoT Security Issues and challenges, Privacy, Overview of Social Engineering.

Text Books

1.	*Joe Bironand Jonathan Follett, Foundational Elements of an IoT Solution – The Edge, The Cloud and Application Development, Oreilly,1st Edition, 2016.*
2.	*Elizabeth Goodman, Alfred Lui, Martin Charlier, Ann Light, Claire Rowland, "Designing Connected Products UX for the Consumer Internet of Things", 2nd Edition, 2013.*
3.	*The Internet of Things (A Look at Real World Use Cases and Concerns), Kindle Edition, Lucas Darnell, 2016.*

References

1.	*Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress 1st ed. Edition, 2017.*
2.	*Olivier Hersent, "The Internet of Things: Key Applications and Protocols", Wiley 2nd Edition, 2012.*
3.	*The Internet of Things – Opportunities and Challenges*
4.	*http://www.ti.com/ww/en/internet_of_things/pdf/14-09-17-IoTforCap.pdf*
5.	*Single Chip Controller and WiFi SOC*
6.	*http://www.ti.com/lit/ds/symlink/cc3200.pdf*
7.	*Wireless Connectivity Solutions*
8.	*http://www.ti.com/lit/ml/swrb035/swrb035.pdf*
9.	*Wireless Connectivity for the Internet of Things – One size does not fit all*
10.	*http://www.ti.com/lit/wp/swry010/swry010.pdf*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the design architecture of IoT.
CO2	Make choice of protocols and deployment in solutions.
CO3	Comprehend the design perspective of IoT based products / services.
CO4	Basic understanding of various Industrial IoT platforms

Course Code	**:**	**IC615**
Course Title	**:**	**Embedded Systems**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide knowledge on building blocks of embedded system, input/output interfacing and Bus communication with processors.
CLO2	To teach automation using scheduling algorithms and real time operating system.
CLO3	To discuss on different phases and modeling of a new embedded product.
CLO4	To involve discussions/ practice/exercise onto revising and familiarizing the concepts

Course Content

Introduction to Embedded Systems –built in features for embedded Target Architecture – selection of Embedded processor –DMA-memory devices –Memory management methods-memory mapping, cache replacement policies-Timer and Counting devices, Watchdog Timer, Graphics Processing Unit (GPU) - multiprocessing and parallel processing, Real Time Clock-Software Development tools-IDE, assembler, compiler, linker, simulator, debugger, In circuit emulator, Target Hardware Debugging.

Embedded Networking: Introduction, I/O Device Ports and Buses - multiple interrupts and interrupt service mechanism – Serial Bus communication protocols - RS232 standard–RS485–USB–Inter Integrated Circuits (I2C) - CAN Bus – Wireless protocol based on Wifi, Bluetooth, Zigbee – Introduction to Device Drivers - interfacing peripherals with processors - Configuration of networking modules - timing and control signals.

Introduction to basic concepts of RTOS-Need, Task, process and threads, interrupt routines in RTOS, Multiprocessing and Multitasking, Preemptive and non-preemptive scheduling, Task communication-context switching, interrupt latency and deadline shared memory, message passing-, Interprocess Communication –synchronization between processes-semaphores, Mailbox, pipes, priority inversion, priority inheritance, comparison of Real time Operating systems: VxWorks, µC/OS-II, RT Linux, Edge computing - Introduction, Edge Operating system Virtual machine, selection of operating system for edge computing, Comparison of Windows and Linux based Edge operating systems, Edge devices, Edge devices in IoT applications.

Modelling embedded systems-embedded software development approach --Overview of UML modeling with UML, UML Diagrams--Hardware/Software Partitioning, Co-Design Approaches for System Specification and modeling – Co Synthesis-features comparing Single- processor Architectures and Multi-Processor Architectures--design approach on parallelism in uniprocessors and Multiprocessors.

Application development: Objective, Need, different Phases andModelling of the EDLC. choice of Target Architectures for Embedded Application Development-for Control Dominated-Data Dominated Systems-Case studies on Digital Camera, Adaptive Cruise control in a Car, Mobile Phone, automated robonoids, interface to sensors, GPS, GSM, Actuators.

Text Books

1.	*Tammy Noergaard, "Embedded System Architecture, A comprehensive Guide for Engineers and Programmers", 2nd Edition, Elsevier, 2013.*
2.	*Peckol, "Embedded system Design", John Wiley and Sons, 2010.*
3.	*Lyla B Das," Embedded Systems-An Integrated Approach", Pearson 2013.*

References

1.	*Elicia White, "Making Embedded Systems", O'Reilly Series, SPD, 2011.*
2.	*Wolf Wayne Hendrix, Computers as Components: Principles of Embedded Computing System Design, 3rd Edition, Morgan Kaufmann, 2012.*
3.	*Shibu K.V, "Introduction to Embedded Systems", Tata Mcgraw Hill, 2009.*
4.	*Raj Kamal, "Embedded System-Architecture, Programming, Design", Mc Graw Hill, 2013.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the functionalities of processor internal blocks, with their requirement.
CO2	Understand the role and features of RT operating system, that makes multitask execution possible by processors.
CO3	Understand multiple CPU based on either hardcore or soft core helps data overhead management with processing- speed reduction for µC execution.
CO4	Design embedded systems to perform dedicated function

Course Code	**:**	**IC616**
Course Title	**:**	**Computer Vision and Image Processing**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the students to the emerging fields.
CLO2	To familiarize with both established and emergent methods, algorithms and architectures.
CLO3	To enable the students to apply computer vision and image processing techniques to solve various real-world problems, and develop skills for research in the field.
CLO4	To impart practical skills necessary to build computer vision applications.

Course Content

Image Formation and Coordinate Transformations, Camera Matrix, Motion/Stereo Pin-hole model, Human eye, cognitive aspects of colour, 3D space; illumination; Sampling and Quantization, Coordinate transformations and camera parameters.

Image Processing - Noise Removal, Blurring, Edge Detection: Canny – Gaussian, Gabor, Texture Edges, Curvature, Corner Detection. Motion Estimation: Horn-Schunk Optical Flow Formulation, Euler-Lagrange formulation: Calculus of variations theory. Structure Recovery from Motion.

Segmentation - Concept of Figure vs. Ground, Watershed, Change Detection, Background Subtraction, Texture Segmentation, Gaussian Mixture Models - Applications in Color and Motion based Image Segmentation, Background Modeling and Shape Clustering.

Machine Learning techniques in Vision, Bayesian Classification, Maximum Likelihood Methods, Neural Networks; Non-parametric models; Manifold estimation, Support Vector Machines; Temporal sequence learning.

Introduction to Object Tracking - Exhaustive vs. Stochastic Search Shapes, Contours, and Appearance Models. Mean-shift tracking; Contour-based models.

Object Modeling and Recognition Fundamental matrix and Epipolar geometry, Adaboost approaches: Face Detection and Recognition, Large Datasets; Attention models.

Applications: Surveillance, Object detection etc.

Text Books

1.	*D. Forsyth and J. Ponce, Computer Vision: A Modern Approach, 2nd Edition, Prentice.*
2.	*Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2011.*

References

1.	*E.R. Davies, Machine Vision, Theory Algorithms Practicalities, Elsevier, 2005.*
2.	*Richard O. Duda, Peter E. Hart, and David G. Stork, Pattern Classification, 2nd ed., Wiley Asia, 2002.*
3.	*Richard Szeliski, Computer Vision: Algorithms and Applications, Springer; 2011.*
4.	*Simon J.D. Prince, “Computer Vision: Models, Learning, and Interference”, Cambridge University Press, 2012.*
5.	*R. Gonzalez and R. Woods, Digital Image Processing, 3rd Ed, Prentice Hall 2007.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the major concepts and techniques in computer vision and image processing
CO2	Demonstrate computer vision and image processing knowledge by designing and implementing algorithms to solve practical problems
CO3	Understand the type of algorithm required for a particular image processing task
CO4	Implement common methods for robust image matching and alignment

Course Code	**:**	**IC617**
Course Title	**:**	**Intelligent Transportation Systems**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	This course covers the techniques used to improve the safety, efficiency and control of surface transportation systems.
CLO2	Emphasis is placed on technological and operational issues of these systems and usingthem for incident detection and for intelligent traffic management.
CLO3	This course provides the current and future Intelligent Transportation Systems (ITS) workforce with flexible, accessible ITS learning through training and educational resources.
CLO4	This course will assist graduate students, educators and transportation professionals in developing their knowledge, skills and abilities to build technical proficiency for ITS.

Course Content

The Road to ITS – History of traffic congestion, Traditional approach to addressing demand vs. capacity, Development of a modern ITS approach, Costs and benefits, Making the case forITS.

Systems Engineering and ITS Architecture – Defining systems engineering and its application to ITS, Benefits of developing ITS architecture, ITS service categories, Regional ITS architecture, Integrating ITS planning with the transportation planning process.

Elements of ITS Design – Interdisciplinary engineering coordination with ITS, Powering ITS equipment, Detection technologies and data collection and distribution, Field device site design considerations, Communications infrastructure.

The Backbone of ITS – Communications network topologies and configuration, Bandwidth requirements, Attributes of hardwired and wireless networks, Fiber-optic networks, Computer IT and ITS synergies. Connected Vehicles – Vehicle-to-vehicle and vehicle-to-infrastructure communications, Safety applications and connected vehicle safety pilot program, Communications security and legal liability, Interoperability and international initiatives.

System Operations and Maintenance – The ITS business, Constructability, Plans, specifications, and cost estimate deliverable package, Maintenance considerations during design, Operational challenges, Ongoing system maintenance, Budgeting support after initial deployment.

Text Books

1.	*Robert Gordon, "Intelligent Transportation Systems: Functional Design for Effective Traffic Management", Second Edition, Springer NY, 2016.*
2.	*Ghosh, S., Lee, T.S, "Intelligent Transportation Systems: New Principles and Architectures", CRC Press, 2000.*

References

1.	*Joseph M. Sussman, "Perspectives on Intelligent Transportation Systems (ITS)", Springer, NY, 2010.*
2.	*Mashrur A. Chowdhury, Adel Sadek, "Fundamentals of Intelligent Transportation Systems Planning", Artech House, 2003.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Study the modern transport systems in a systematic and focused way.
CO2	Understand the fundamentals of ITS, including ITS national/regional architectures, designing process and the state-of-the-practice technologies.
CO3	Grasp technological and operational issues of ITS and using them for connected vehicles.
CO4	Think mobility further through adaptable and modular solutions.

Course Code	**:**	**IC618**
Course Title	**:**	**Wireless Sensor Networks**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To overview the various design issues and challenges in the layered architecture ofWireless sensor networks.
CLO2	Analyze various protocols used in wireless sensor networks.
CLO3	To familiarize localization and tracking in networks
CLO4	Learn about data handling in wireless sensor networks.

Course Content

Introduction to Sensor Networks - Unique constraints and challenges, Advantage and Applications of Sensor Networks, Enabling technologies for Wireless Sensor Networks. Sensor Node Hardware and Network Architecture: Single-node architecture, Hardware components and design constraints, Operating systems and execution environments, Network architecture, Optimization goals and figures of merit, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts.

Physical layer- Introduction, wireless channel and communication fundamentals – frequency allocation, modulation and demodulation, wave propagation effects and noise, channels models, spread spectrum communication, packet transmission and synchronization, quality of wireless channels and measures for improvement, physical layer and transceiver design consideration in wireless sensor networks.

Data link layer- Fundamentals of wireless MAC protocols, Characteristics of MAC protocol in wireless sensor networks contention-based protocols, Contention free MAC protocols, Hybrid MAC protocols Network layer-routing metrics -Flooding and gossiping. Routing protocols: Issues in designing routing protocols, Classification of routing protocols, Energy-efficient routing, Unicast, Broadcast and multicast, Geographic routing.

Localization and tracking – A tracking scenario, tracking multiple objects, sensor models, performance comparison and metrics, Networking sensors – MAC, general issues, geographic energy – aware routing, Attribute – Based routing. Deployment and Configuration: Localization and positioning, Coverage and connectivity, Single-hop and multi-hop localization, self-configuring localization systems, sensor management

Data Storage and Manipulation: Data centric and content-based routing, storage and retrieval in network, compression technologies for WSN, Data aggregation technique. Case study- Detecting unauthorized activity using a sensor network, Target detection tracking, Habitat monitoring, Environmental disaster monitoring, Practical implementation issues, IEEE 802.15.4 low rate WPAN, Operating System Design Issues. Simulation tools.

Text Books

1.	*W. Dargie, C. Poellabauer, "Fundamentals of Wireless sensor networks -Theory and Practice", John Wiley and Sons Publication, 2010.*
2.	*K. Sohraby, D. Minoli and T. Znati, "Wireless Sensor Network Technology Protocols and Applications", John Wiley and Sons, 2007.*
3.	*HolgerKerl, Andreas Willig, "Protocols and Architectures for Wireless Sensor Network", John Wiley and Sons, 2005.*
4.	*Feng Zhao, Leonidas Guibas, "Wireless Sensor Network", 1st Ed., Elsevier, 2004.*

References

1.	*F. Zhao, L.Guibas, "Wireless Sensor Networks: an information processing approach", Elsevier publication, 2004.*
2.	*C. S. Raghavendra Krishna, M. Sivalingam and Taribznati, Wireless Sensor Networks", Springer publication, 2004.*
3.	*H. Karl, A.willig, "Protocol and Architecture for Wireless Sensor Networks", John Wiley publication, Jan 2006.*
4.	*Kazem, Sohraby, Daniel Minoli, TaiebZanti, "Wireless Sensor Network: Technology, Protocolsand Application", 1st Ed., John Wiley and Sons, 2007.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Analyze the challenges and constraints of wireless sensor network and its subsystems.
CO2	Examine the physical layer specification, modulation and transceiver design considerations.
CO3	Compare and analyze the types of routing protocols and data aggregation techniques.
CO4	Identify the application areas and practical implementation issues.

Course Code	**:**	**IC619**
Course Title	**:**	**Fluid Power Systems**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the role of pneumatic and hydraulic systems in industrial automation.
CLO2	To impart the principles of various pneumatic and hydraulic components.
CLO3	To facilitate the design of hydraulic and pneumatic circuits.
CLO4	To familiarize the operation, maintenance and troubleshooting of various fluid power system in industry.

Course Content

Introduction to fluid power, applications, advantages and limitations. Types of fluid power systems, Properties, Types of fluids – Fluid power symbols. Basics of hydraulics - applications of Pascal's Law – Laminar and Turbulent flow – Reynolds's number – Darcy's equation – Losses in pipe, valves and fittings.

Hydraulic system and components: Hydraulic Pumps – Classification, reciprocating, rotary, centrifugal, working principle, performance characteristics, selection and design considerations. Fluid Power Actuators – Linear hydraulic actuators and types – Semi-rotary and rotary actuators.

Pneumatic system and components: Introduction to Pneumatics – Compressors – Types – Air treatment – FRL Unit – Air control valves, Quick exhaust valves, pneumatic actuators. Fluid power circuit design, Speed control circuits, synchronizing circuit, Pneumo-hydraulic circuit, Sequential circuit design.

Design of fluid power circuits: Control Valves – Directional, Pressure and Flow control valves. Accumulators – Types, Accumulators circuits. Intensifier – Applications – Intensifier circuit. Servo systems – Hydro mechanical servo systems, Electro hydraulic servo systems and proportional valves.

Fluid power system maintenance and troubleshooting: Fluidics – Introduction to fluidic devices. Fluid power circuits; failure and troubleshooting.

Text Books

1.	*Vickers. Industrial Hydraulics Manual, 6th ed., Eaton Hydraulics Training Services, 2015.*
2.	*Anthony Esposito, Fluid Power with Applications, 7th ed., Pearson Education India, 2013.*
3.	*Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, 2nd ed., Pearson, 1986.*
4.	*P. Joji, Pneumatic Controls, 1st ed., Wiley India, 2008*

References

1.	*Srinivasan. R, Hydraulic and Pneumatic controls, 2nd ed., McGraw Hill Education, 2008.*
2.	*Majumdar. S, Pneumatic systems – Principles and maintenance, 1st ed., Tata McGraw Hill Education, 2017.*
3.	*Michael J, Pinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1988.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the basics of fluid power system.
CO2	Select the appropriate pneumatic and hydraulic system for a given application.
CO3	Implement various fluid power circuits.
CO4	Operate, maintain and troubleshoot industrial fluid power circuits.

Course Code	**:**	**IC620**
Course Title	**:**	**Augmented Reality**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To study the fundamentals of Augmented Reality (AR) modeling and programming
CLO2	To understand the tools and platforms used in the AR and Virtual Reality (VR).
CLO3	To learn the principles and multidisciplinary features of virtual reality
CLO4	To develop virtual environments and simulators

Course Content

Augmented reality and virtual reality - The historical development of AR and Virtual Reality: Scientific landmarks Computer Graphics, Real-time computer graphics, Flight simulation, Virtual environments, Requirements for AR and VR, benefits of AR and VR.

Hardware technologies for 3D user interfaces: Visual Displays Auditory Displays, Haptic Displays, Choosing Output Devices for 3D User Interfaces. Input device characteristics, Desktop input devices, Tracking Devices, 3D Mice, Special Purpose Input Devices, Direct Human Input, Home - Brewed Input Devices, Choosing Input Devices for 3D Interfaces.

Software technologies: Database - World Space, World Coordinate, World Environment, Objects - Geometry, Position / Orientation, Hierarchy, Bounding Volume, Scripts and other attributes, AR Environment - AR Database, Tessellated Data, LODs, Cullers and Occludes, Lights and Cameras, Scripts, Interaction - Simple, Feedback, Graphical User Interface, Control Panel, 2D Controls, Hardware Controls, Room / Stage / Area Descriptions, World Authoring and Playback, AR toolkits, Available software in the market.

3D interaction techniques - 3D Manipulation tasks, Manipulation Techniques and Input Devices, Interaction Techniques for 3D Manipulation, Design Guidelines - 3D Travel Tasks, Travel Techniques, Design Guidelines - Theoretical Foundations of Wayfinding, User Centered Wayfinding Support, Environment Centered Wayfinding Support, Evaluating Wayfinding Aids, Design Guidelines - System Control, Classification, Graphical Menus, Voice Commands, Gestural Commands, Tools, Multimodal System Control Techniques, Design Guidelines, Case Study: Mixing System Control Methods, Symbolic Input Tasks, symbolic Input Techniques, Design Guidelines, Beyond Text and Number entry.

Designing and developing 3d user interfaces - Strategies for Designing and Developing Guidelines and Evaluation-3D User Interfaces for the Real World, AR Interfaces as 3D Data Browsers, 3D Augmented Reality Interfaces, Augmented Surfaces and Tangible Interfaces, Agents in AR, Transitional AR-VR Interfaces - The future of 3D User Interfaces, Questions of 3D UI Technology, 3D Interaction Techniques, 3D UI Design and Development, 3D UI.

Evaluation and Other Issues. Engineering, Architecture, Education, Medicine, Entertainment, Science, Training.

Text Books

1.	*Alan B Craig, William R Sherman and Jeffrey D Will, "Developing Virtual Reality Applications: Foundations of Effective Design", Morgan Kaufmann, 2009.*
2.	*Gerard Jounghyun Kim, "Designing Virtual Systems: The Structured Approach", Springer Verlag London, 2005.*
3.	*Doug A Bowman, Ernest Kuijff, Joseph J LaViola, Jr and Ivan Poupyrev, "3D User Interfaces, Theory and Practice", Addison Wesley, USA, 2004.*
4.	*Oliver Bimber and Ramesh Raskar, "Spatial Augmented Reality: Meging Real and Virtual Worlds", CRC Press 2005.*

References

1.	*Burdea, Grigore C and Philippe Coiffet, "Virtual Reality Technology", Wiley IEEE, 2003.*
2.	*John Vince, "Virtual Reality Systems", Pearson Education, 1995.*
3.	*Howard Rheingold, "Virtual Reality: The Revolutionary Technology and how it Promises to Transform Society", Simon and Schuster, 1991.*
4.	*William R Sherman and Alan B Craig, "Understanding Virtual Reality: Interface, Application and Design (The Morgan Kaufmann Series in Computer Graphics)". Morgan Kaufmann Publishers, San Francisco, CA, 2002.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand AR models and programs.
CO2	Develop 3D interaction techniques.
CO3	Design 3D user interface.
CO4	Apply AR and VR tools for various industrial applications.

Course Code	**:**	**IC621**
Course Title	**:**	**Advanced Control Systems**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge in characteristics and performance of feedback control system.
CLO2	To introduce about the system states and state-space modeling of dynamical systems.
CLO3	To teach the advanced methods and techniques of linear system analysis and stability using Lyapunov theory.
CLO4	To develop practical control systems using digital computers through data acquisition and computing.

Course Content

Introduction to basic control theory, Requirements for Control System Design, Mathematical Models for Control, Control System 's Characteristics, Performance Specifications for Linear Systems.

State-space Models – Review of vectors and matrices, Canonical Models from Differential Equations and Transfer Functions, Interconnection of subsystems. Analysis of Linear State Equations – First order scalar differential equations, System modes and model decomposition, State Transition Matrix, Time-varying matrix case.

Lyapunov's stability theory for Linear Systems – Equilibrium points and stability concepts, Stability definitions, linear system stability, The Direct method of Lyapunov, Use of Lyapunov's method in feedback design.

Controllability and Observability – Definitions, Controllability/Observability Criteria, Design of state feedback control systems, Full-order and Reduced-order Observer Design, Kalman canonical forms, Stabilizability and Detectability.

Digital Control Systems, Closed-loop Feedback Sampled-Data Systems, Stability Analysis, Implementation of Digital Controllers.

Text Books

1.	*Katsuhiko Ogata, Modern Control Engineering, PHI Learning Private Ltd, 5th Edition, 2010.*
2.	*Franklin, G.F., David Powell, J., Emami-Naeini, A., Feedback Control ofDynamic Systems, Prentice Hall, 7th Edition, 2014.*
3.	*Dorf, R.C., Bishop, R.H., Modern Control Systems, Prentice Hall, 13th Edition, 2016.*
4.	*Brogan, W.L., Modern Control Theory, Prentice Hall, 3rd Edition, 1990.*

References

1.	*John J.D., Azzo Constantine, H. and Houpis Stuart, N Sheldon, Linear Control System Analysis and Design with MATLAB, CRC Taylorand Francis Reprint 2009.*
2.	*I.J. Nagrath and M. Gopal, Control Systems Engineering, New Age International Publishers, 6th Edition, 2017.*
3.	*William A. Wolovich, Automatic Control Systems, Oxford University Press, 1st Indian Edition 2010.*

Course Outcomes (CO)

At the end of the course student will be

CO1	Exposed to an appropriate modern paradigm for the study of larger scale multi-input-multi- output systems.
CO2	Able to use linear algebra and matrix theory in the analysis and design of practical control systems.
CO3	Able to determine the stability of systems using Lyapunov's theory.
CO4	Motivated to implement modern control systems using a digital computer.

Course Code	**:**	**IC622**
Course Title	**:**	**Networked Control Systems**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce different models of network control system.
CLO2	To introduce different estimation techniques for network control system.
CLO3	To introduce different network control system techniques.
CLO4	To introduce different applications suited for network control systems.

Course Content

Stochastic process – Introduction to random variables, Expectations, Moments, stationary and non- stationary process.

Network models – Stochastic model, communication network constraints, packet delay, packet loss, uncertain observation, Markov chain-based model.

Estimation of networked control system – Observer for networked system, Kalman filter. Control strategies – Output feedback control, Predictive control.

Introduction to graph theory, Simulation of network control system, Application of network control system.

Text Books

1.	*J. Medhi, "Stochastic Processes", 3rd Edition, New Age Science, 2009.*
2.	*Jagannathan Sarangapani, Hao Xu, "Optimal Networked Control Systems with MATLAB", 1st Edition, CRC press, Taylor and Francis group, 2016.*
3.	*Xia Y., Fu M., Liu GP., "Analysis and Synthesis of Networked Control System, Lecture Notes in Control and Information Sciences", Springer-Verlag Berlin Heidelberg, 2011.*

References

1.	*Anderson, B.D.O. and Moore J.B., "Optimal Filtering", Prentice-Hall, Englewood Cliffs, New Jersey, 1979.*
2.	*K You, N Xiao, L Xie, "Analysis and Design of Networked Control System, Communications and Control Engineering", Springer London Heidelberg New York Dordrecht, 2015.*
3.	*Srikant, Rayadurgam, Lei Ying, "Communication networks: an optimization, control, and stochastic networks perspective. Cambridge University Press,2013*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Model the network control system with packet delay, loss and uncertain observation.
CO2	Design control system in the presence of quantization, network delay or packet loss.
CO3	Understand distributed estimation and control suited for network control system.
CO4	Develop simple application suited for networked control systems.

Course Code	**:**	**IC623**
Course Title	**:**	**System Identification**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge about the importance of system identification.
CLO2	To introduce empirical and data-based modeling of large-scale systems.
CLO3	To train the students in parametric and nonparametric statistical models and estimationtechniques.
CLO4	To expose the students to the algorithms and computational overheads involved inlarge-scale system modeling and control.

Course Content

Review of linear systems, stochastic process- statistical properties, signal stationarity, auto-correlation, cross-correlation, and power spectra - System identification Procedure- Experimental design – Input design for identification, notion for persistent excitation (pulse, step, pseudo random binary sequence (PRBS), and white noise) - data processing - Model structure determination - Estimation techniques - Model validation.

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

Parametric model structures: Time series models (AR, MA, ARMA, ARIMA, ARX, ARMAX, OE, BJ models) – Order determination of time series models using correlation- prediction error models of parametric models.

Linear regression - Least square estimates, statistical properties of LS Estimates- bias and consistency, Weighted least squares, maximum likelihood estimation, Instrumental variable method- square Residual analysis for determining adequacy of the estimated models.
Recursive Algorithms: Least squares, Instrumental Variables, extended least square, prediction error methods. Kalman filter, Extended Kalman filtering and its applications.

Simulation study for different processes: Design of experiment, nonparametric identification, parametric identification, influence of different inputs on ARX, ARMAX modelling, use of identified model for fault diagnosis, estimation, prediction and control of the process.

Text Books

1.	*Arun K. Tangirala, "Principles of System Identification: Theory and Practice", 1st Edition, CRC Press, 2014.*
2.	*L. Ljung, "System Identification: Theory for the User", 2nd Edition, Prentice- Hall, 1999.*
3.	*Rolf Johansson, "System Modeling and Identification", Prentice Hall, 1993.*

References

1.	*Karel J. Keesman, "System Identification an Introduction", Springer-Verlag London, 2011.*
2.	*Y. Zhu, "Multivariable System Identification for Process Control",1st Edition, Pergamon Elsevier Science, 2001.*
3.	*O. Nelles, "Nonlinear System Identification", Springer-Verlag Berlin Heidelberg, 2001.*
4.	*B. Roffel and B. Betlem, "Process Dynamics and Control", Wiley, 2006.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Conduct experiments, design suitable inputs and generate data for system identification.
CO2	Identify the model structure and order determination for an unknown process fromempirical data.
CO3	Apply estimation techniques for parametric and nonparametric models.
CO4	Identify and validate the model for practical process applications.

Course Code	:	**IC624**
Course Title	:	**Cyber Security in Industrial Automation**
Type of Course	:	PE
Credits / Contact Hours	:	3 / 42 hours
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the knowledge of internet along with the changing trends in the cyber technologies.
CLO2	Understand the various security threats and vulnerabilities of the cyber world keeping in line with the industrial trends.
CLO3	Understand how web technology works, how web server capability is used in industry, and the security problems engendered by such use.
CLO4	Locate web technologies where they can be used securely for industrial automation

Course Content

Industrial Automation Fundamental Concepts - Industrial automation protocol summary-The Open System Interconnection (OSI) Model, The Transmission Control Protocol (TCP)/ Internet protocol (IP) Model, Object linking and embedding for process control, Open platform communication (OPC) Unified architecture, Modbus/ TCP Model, The distributed network protocol, Controller area network, Ethernet/ IP, Open safety protocol.

Information System Security Technology- Types and classes of attack, Policies, Standards, Guidelines and procedures, Malicious code and attacks, Firewalls, Cryptography, Attacks against cryptosystems.

Industrial Automation Culture versus Information Technology (IT) Paradigms- Considerations in adapting IT security methods to industrial automation, Threats, IT and industrial automation.

Risk Management for Industrial Automation- Risk management, ANSI/ISA-62443-2-1 (99.02.01)-2009 cyber security, Risk analysis, Addressing risk, NIST SP 800-39 Integrated enterprise risk management, Threats.

Industrial Automation Trends, Approaches, and Issues- Automation trends, Formal methods used to quantify and standardize important concepts and applications -Information security continuous monitoring (ISCM) strategy, The Smart Grid Maturity Model (SGMM), Future smart grid issues and automation security issues.

Emerging Approaches to Industrial Automation Security- Internet of Things, Open platform communications unified architecture, Security and privacy, big data analytics and the industrial Internet of Things, The National Institute of Standards Technology (NIST) Cyber-Physical Systems (CPS) Framework, CPS and Cybersecurity, Critical Infrastructure security, Software-defined elements.

Text Books

1.	*Ronald L. Krutz, "Industrial Automation and Control System Security Principles: Protecting the Critical Infrastructure", 2nd Edition, International Society of Automation, 2017.*
2.	*David J. Teumim, "Industrial Network Security, Second Edition", International Society of Automation, 2010.*

References

1.	*Lawrence M. Thompson and Tim Shaw, "Industrial Data Communications", Fifth Edition, International Society of Automation, 2015.*
2.	*Dick Caro, "Automation Network Selection: A Reference Manual", 3rd Edition, Paperback, International Society of Automation, 2016.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Get knowledge of security mechanisms, standards and state-of–the-art capabilities.
CO2	Design new systems and infrastructure level security solutions.
CO3	Develop and maintain new tools and technologies to enhance the security of applications in industrial automation.
CO4	Identify and solve different cyber security threats.

Course Code	**:**	**IC625**
Course Title	**:**	**Building and Infrastructure Systems and Automation**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand, illustrate the need and concept of building, infrastructure subsystems, systems and automation.
CLO2	Select, architect, size, design and implement the building and infrastructure main andauxiliary sub-systems, systems, automation.
CLO3	Perform and improve operations and maintenance of building, infrastructure subsystems, systems automation including energy and utility optimization.
CLO4	Learn recent trends, research-topics, expansion areas of Building and Infrastructuresystem automation and management.

Course Content

Introduction to Building and Infrastructure Systems and Automation:
Overview of buildings and campuses – residential community, commercial, industrial, Concept and application of buildings automation (BA), Requirements and design considerations of BA. Effect on energy and utility services efficiency of building services operations. Architecture and components of BA, BMS (Building Management Systems) concept and overview.

Beyond traditional buildings: Other important infrastructures – commercial/industrial campuses, malls, high-rise buildings, hotels and resorts, sports-complex, smart-community and smart-city, metro-trains, airports, seaports, ships, surface transports (road-bridges, highways, waterways).

Buildings and Infrastructure Systems: Typical subsystems HVAC**:** Different components of HVAC system like heating, cooling system, chillers, AHUs, compressors, distribution systems, air-quality, filters units and their types, operational efficiency and economics, Community/district heating and cooling.

Lighting and Access control systems: Various components of lighting systems, efficient use of electricity, lighting control systems, components of CCTV system like cameras, cables, etc., concept of automation in access control system.

Vertical transportation System: Structure of lift and escalator, traffic analysis, lift drives, supervisory control and remote monitoring of lift, safety aspects.

Fire and Alarm system: Different fire sensors, smoke detectors and their types, CO and CO2 sensors, Fire control panels, design considerations for the FA system concept of IP enabled fire and alarm system, design aspects and components of PA system.

Other utility and subsystems: Water sources-storage-distribution, rain-water harvesting, sewage treatment plants, swimming pool, cooking gas source-distribution system, community halls and gym, air/gas utility supply and distribution systems, facility-estate management, safety, OandM.

Electrical Utility: Typical sources - power-grid utility and diesel-gensets, stable and uninterrupted power supply, components of electrical power distribution in buildings-infrastructure, transformers, meters, distribution system components, wiring, common/large loads – pumps, compressors, motors and drives, VFDs.

Building Automation: Role of automation in operation of BandI System/subsystems (HVAC/Lighting/Lifts/Electricity etc.). Relevant sensors-actuators, BA controllers DDC, PLC, SCADA, HMI, RMVCD Centers.

Energy management systems: Bureau of Energy Efficiency (BEE) standards, concept of energy management systems, Energy Optimization, Green-energy and Zero-energy Buildings, Certification.

Thermal energy: Sources-distribution-sinks components, thermal energy systems modeling and simulation for buildings/infrastructure, Heat-recovery, Solar heating, typical simulation tools Electrical energy and microgrids: Sources-distribution-sinks components, power-utility grid, diesel-gas gensets, Campus Micro-grids -- renewable energy sources (solar/wind/battery storage etc.), CHP, electrical vehicle charging infrastructure, electrical energy systems modeling and simulation for buildings/infrastructure, typical simulation tools.

Self-Study Topics:
Recent and Advanced Topics:
Overview of recent trends/topics like Automation for special buildings/infrastructures like metros, airports, seaports, high-rise buildings, hotels and resorts, sports-complex, smart-community, smart-city etc.; Microgrid advances, BMS, Cybersecurity, Optimization, AI-ML in BMS, assets and human-comforts analytics, post-pandemic health and safety trends in BMS, etc.

References

1.	*Smart Buildings by Jim Sinopoli, Butterworth-Heinemann imprint of Elsevier, 2nd ed., 2010.*
2.	*Understanding Building Automation Systems (Direct Digital Control, Energy Management, Life Safety, Security, Access Control, Lighting, Building Management Programs) by Reinhold A. Carlson, Robert A. Di Giandomenico, pub. by R.S. Means Company, 1991.*
3.	*Intelligent Building Systems by Albert Ting-Pat So, WaiLok Chan, Kluwer Academic publisher, 3rd ed., 2012.*

4.	*Design of Special Hazards and Fire Alarm Systems by Robert Gagnon, Thomson Delmar Learning; 2nd edition, 2007.*
5.	*HVAC Controls and Systems by Levenhagen, John I. Spethmann, Donald H., McGraw-Hill Pub.*
6.	*HVAC Control in the New Millennium by Hordeski, Michael F, Fairmont press, 2001.*
7.	*Process Control- Instrument Engineers Handbook by Bela G. Liptak, Chilton book co.*
8.	*Other resources like Published journal/conference papers, industrial products and manuals, Internet search/survey.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the architecture and basic building blocks of Building and Infrastructure of Automation systems
CO2	Design and evaluate various subsystems for Building Automation systems
CO3	Design and implement control strategies for HVAC systems for energy management system
CO4	Grasp the advanced principles for incorporating the safety and acquire efficient resource management skills within Building Automation systems.

Course Code	**:**	**IC626**
Course Title	**:**	**Rapid Prototyping**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce about different classes of Rapid Prototyping (RP) systems.
CLO2	To impart knowledge about applications of various RP processes.
CLO3	To introduce about rapid tooling.
CLO4	Understand about RP Technology selection.

Course Content

Introduction- Need for the compression in product development, History of Rapid Prototyping (RP)systems, Survey of applications, Growth of RP industry, Classification of RP systems.

Principle, process parameters, process details and applications of various RP processes - Stereo lithography systems, Laser Sintering, Fused Deposition Modeling, and Laminated Object.

Manufacturing, Solid Ground Curing, Laser Engineered Net Shaping, 3D Printing, Laser Melting, Cladding.

Rapid Tooling - Indirect rapid tooling, Direct rapid tooling, soft tooling Vs hard tooling, Rapid Manufacturing Process Optimization- Factors influencing accuracy, data preparation errors, part building errors, errors in finishing, influence of part build orientation.

Software for RP - STL files, Overview of solid view, Magics, mimics, magics communicator, etc., internet-based software, collaboration tools. RP Technology selection, Decision Making, Life CycleAssessment of RP processes, Sustainability issues.

Text Books

1.	*Prasad H and Badrinarayanan, K S, "Rapid Prototyping and Tooling", SPI-Pageturners, Bangalore, India, 2013.*
2.	*Hilton P, Jacobs P F, "Rapid Tooling: Technologies and Industrial Applications", 1st Edition CRC press, 2000.*

References

1.	*Pham D T and Dimov S S, "Rapid Manufacturing",* Springer*Verlag, 2001.*
2.	*Paul F Jacobs, "Stereo lithography and other RPandM Technologies", SME, 1996.*
3.	*Terry Wohlers, "Wohlers Report 2001", Wohlers Associates, 2008.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the importance of time compression technologies
CO2	Select of appropriate technology for particular application.
CO3	Apply RP software packages
CO4	Recognize various types of rapid tooling.

Course Code	**:**	**IC627**
Course Title	**:**	**Predictive Analytics**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Ability to develop and use various predictive models based on various regression and decision tree methods.
CLO2	Understand how to formulate predictive analytics questions.
CLO3	Learn how to select the appropriate method for predictive analysis.
CLO4	Learn how to search, identify, gather and pre-process data for the analysis

Course Content

Statistical Learning and Linear Regression- Supervised versus unsupervised learning, the trade-Off between prediction accuracy and model interpretability, Regression versus classification problems, Simple linear regression, Multiple linear regression, Considerations in the regression model, Comparison of linear regression with K-Nearest Neighbors, Weighted Least Squares (WLS), Generalized Linear Models (GLM).

Overview of Classification and data processing- Logistic Regression - Logistic model, Estimating the regression coefficients, making predictions, Multiple logistic regression, Linear Discriminant Analysis- Using Bayes' theorem for classification, Quadratic Discriminant Analysis, Comparison of classification methods, Data preprocessing- Overview, Variable types, Data transformations, Count data models, Centering, Standardization, Rank transformations, Data reduction.

Linear Model Selection and Regularization- Subset selection, Dimension reduction methods- Principal components regression, Partial least squares, Considerations in high dimensions, regression in high dimensions. Tree-Based Methods- The basics of decision trees, Regression trees, Classification trees, Trees versus linear models, Advantages and disadvantages of trees, Bagging, Random forests, Boosting.

Predictive Modelling - Statistical concepts – Basics, Introduction to predictive modelling, Neural networks and other modelling tools, Model assessment and implementation, Support Vector Machine (SVM), Cross tabulation and correlation analysis.

Unsupervised Learning- The challenge of unsupervised learning, Principal Components Analysis (PCA), Use of principal components, Clustering methods, K-means clustering, Hierarchical clustering

Machine Learning - Machine learning overview, Error measures, Cross-validation, Bias vs. variance tradeoff.

Text Books

1.	*Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey,"Business analytics Principles, Concepts, and Applications", by Pearson FT Press,2014.*
2.	*James Evans, "Business Analytics", 1st Edition, Persons Education, 2012.*

References

1.	*Gareth James, Daniela Witten, Trevor Hastie Robert Tibshirani, "An Introduction to Statistical Learning with Applications in R", 1st Edition, Springer, 2017.*
2.	*Lander, J., "R for Everyone: Advanced Analytics and Graphics", 1 edition Addison-Wesley Data and Analytics Series, 2013.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Develop a deep understanding of the predictive analytics life cycle.
CO2	Work with various data types and how to pre-process the data for analysis.
CO3	Learn the basic concepts behind machine learning.
CO4	Learn the various methods to build predictive classification models using decisiontrees.

Course Code	**:**	**IC628**
Course Title	**:**	**Optimization Techniques**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To Introduce linear programming problem and to learn various methods to solve it.
CLO2	To study essential optimization techniques and algorithms to solve one dimensional and multidimensional optimization problems.
CLO3	To discuss the optimality conditions for the constrained and unconstrained optimization problems.
CLO4	To model and solve Shortest-Route, allocation and production scheduling problems using dynamic programming

Course Content

Linear programming – Formulation - Graphical and simplex methods - Big-M method - Two phase method - Dual simplex method - Primal Dual problems.

Unconstrained one-dimensional optimization techniques - Necessary and sufficient conditions – Unrestricted search methods - Fibonacci and Golden section method - Quadratic Interpolation methods, cubic interpolation.

Unconstrained multi-dimensional optimization techniques – Direct search methods – Random search – Pattern search - Descent methods - Steepest descent and conjugate gradient.

Constrained optimization Techniques - Necessary and sufficient conditions – Equality and inequality constraints - Kuhn-Tucker conditions - Gradient projection method - Cutting plane method - Penalty function method.

Dynamic programming - Principle of optimality - Recursive equation approach - Application to shortest route, cargo - loading, allocation and production schedule problems.

Text Books

1.	*Rao, S.S., 'Engineering Optimization: Theory and Practice', New Age International, 3rd edition, 2018.*
2.	*Taha, H. A., 'Operations Research –An Introduction', Pearson Education, 10th edition, 2018.*
3.	*Fox, R.L., 'Optimization methods for Engineering Design', Addison Wesley, 1981.*

References

1.	*Mokhtar S. Bazaraa, Hanif D. Sherali and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley, 2013.*
2.	*A. Ravindran, Don T. Phillips and James J. Solberg, Operations Research- Principles and Practice, John Wiley, 2014.*
3.	*Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw Hill, 2010.*
4.	*Kanti Swarup, P.K. Gupta and Man Mohan, Operations Research, Sultan Chand,2014.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand formulation of linear programming-based problems and apply graphical andsimplex methods.
CO2	Apply appropriate optimization technique and analyze unconstrained one-dimensional problems
CO3	Apply appropriate optimization technique and analyze unconstrained multi-dimensional problems.
CO4	Appraise and evaluate constrained optimization problems related to Industrial Automation problems by appropriate methods

Course Code	**:**	**IC629**
Course Title	**:**	**Advanced Sensor Interfacing and Measurement Circuits**
Type of Course	**:**	PE/OE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide expertise in designing analog signal conditioning circuits specifically for resistive and capacitive sensors, with the goal of enhancing their performance characteristics.
CLO2	To provide knowledge on designing transmitters that adhere to industrial standards.
CLO3	To impart understanding of data acquisition system design and address associated challenges.
CLO4	To provide knowledge about modern digital interfaces for sensors.

Course Content

Introduction to operational amplifier (op-amp), circuits with resistive and capacitive feedback, effect of non-idealities of op-amp on circuit performances, Howland current pump, current amplifier, difference and instrumentation amplifier, Transducer Bridge amplifier. Op-amp limitation, static error, bias and offset currents and voltages, dynamic limitation, open and closed loop frequency response, input and output impedances, transient response, gain bandwidth product (GBP), effect of GBP on op-amp circuit, isolation amplifier, grounding and shielding.

Interfacing circuits for resistive and capacitive sensors, enhancement of linearity, sensitivity, resolution, temperature compensation, power dissipation, addressing self-heating errors, managing current limits, evaluating circuit range and dynamic response. Noise analysis of interface circuits.

Designing two-wire, three-wire, and four-wire transmitters for sensors, lead resistance compensation, and precise 4-terminal low-resistance measurements, data acquisition system, analog to digital conversion, dual slope integrator, issues related to interfacing of static and dynamic sensors.

Digital sensor system design, interfacing circuits (digitizer) for resistive and capacitive sensor. Direct microcontroller interface (DMI) for resistive and capacitive transducers: design and practical implementation. Modern digital interfacing circuit based on switched capacitor (SC) and sigma-delta modulators. Case studies and hands-on for digital interface for sensors for industrial applications.

References

1.	*Ramon Pallas-Areny, John G. Webster, Sensors and Signal Conditioning, 2/e, Wiley India, 2012*
2.	*Walt Kester, Practical Design Techniques for Sensor Signal Conditioning, Analog Devices, 1999*
3.	*Daniel H. Sheingold, Transducer Interfacing Handbook, Analog Devices, 1980*
4.	*Walt Kester, Practical Analog Design Techniques, Analog Devices, 1995*
5.	*Sergio Franco, Design with Operational Amplifiers and Analog Integrated Circuits, 4/e, TMH, 2016*
6.	*William D. Stanley, Operational Amplifiers with Linear Integrated Circuits, 6/e, Pearson Education, 2004*
7.	*James Fiore, Operational Amplifiers and Linear Integrated Circuits, Jaico Publishing House, 1/e, 1999*
8.	*Robert F Coughlin, Frederick F. Driscoll, Operational amplifiers and Linear Integrated Circuits, 6/e, Pearson Education, 2015*
9.	*James W. Dally (Author), William F. Riley (Author), Kenneth G. Mcconnell, Instrumentation for Engineering Measurements, 2/e, Wiley India, 2010*
10.	*John P Bentley, Principles of Measurement Systems, 4/e Pearson Pentice Hall, 2005*
11.	*Ernest O. Doebelin (Author), Dhanesh N. Manik, Measurement Systems, 7/e, McGraw-Hill, 2019*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Design electronic interface circuits for resistive and capacitive sensors.
CO2	Design analog electronic circuits and integrated circuit-based transmitters for specified physical parameters.
CO3	Design digital interface circuits for resistive and capacitive sensors.
CO4	Design modern digital interfaces for sensors.

Course Code	**:**	**IC630**
Course Title	**:**	**Automation in Financial Technology**
Type of Course	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To gain familiarity with the current economic reforms and trends
CLO2	To understand how technology influences Economics and Finance
CLO3	To explore incorporating Extreme Automation into the FinTech processes to scale up and efficiently serve a vast variety of consumers
CLO4	To get exposed to the future trends such as quantum computing, financial regulations etc.,

Course Content

Introduction to FinTech, Fintech history and evolution, Current Landscape, Online payments, Digital Wallets etc., Digital Banking, Alternative Funding, Personal Finance Management, Real-Time data and analytics, Trends in Automation from Basic Automation (BA in 2010) to Extreme Automation (XA since 2021), Role of AI and ML; Economy, Ethics and Automation.

Robotic Process Automation (RPA), Introduction to UiPath tool.

Robotic Process Mining (RPM) for Developing Extreme Automation (XA) environment.

Use cases in Customer onboarding, Compliance, Credit Card Processing, Fraud detection, Dispute Resolution, etc.

Introduction to Advanced Topics: Blockchain and Decentralized Finance, Quantum Computing, Cross-border Financial Regulations, VR and AR, AI Powered Financial Regulations.

References

1.	*Richard Murdoch, Robotic Process Automation: Guide to Building Software Robots, Automate Repetitive Tasks and Become an RPA Consultant, independently published. ISBN: 978-1983036835*
2.	*Wil M. P. van der Aalst, Josep Carmona (Ed.), Process Mining Handbook, Lecture Notes in Business Information Processing (LNBIP, vol. 448), eBook ISBN: 978-3-031-08848-3, Springer Cham, 2022. Open Access*
3.	*Frederick P Brooks Jr., The Mythical Man-Month: Essays on Software Engineering, Addison Wesley Longman Publishing Co., 1974.*
4.	*Klaus Schwab, Shaping the Future of the Fourth Industrial Revolution, Penguin, 2018.*

5.	*Christian Madsbierg, Sensemaking: What Makes Human Intelligence Essential in the Age of the Algorithms, Abacus Books, 2019*
6.	*Marek Kowalkiewicz, The Economy of Algorithms, Simon and Schuster, India, 2024*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Familiar with the Basics of Financial Technology
CO2	Implement the Robotic Process Automation
CO3	Implement the AI Powered Automation
CO4	Apply the Commercial tools such as UiPath

Course Code	**:**	**IC631**
Course Title	**:**	**Nonlinear Control**
Type of Course	**:**	PE
Prerequisites	**:**	MAIR courses (UG), MA 623 (PG)
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce and elaborate the characteristics of nonlinear systems
CLO2	To gain understanding in the methods (both classical and modern) of analysis of stability and performance of nonlinear systems
CLO3	To study the design of controllers as applicable to robotics, aerospace etc.
CLO4	To introduce complex systems theory and large-scale real-world problems

Course Content

Introduction – Modelling one-dimensional and two-dimensional dynamics, Existence and uniqueness of solutions.

Approximate Analysis methods: The phase plane, Index theory, Poincare-Bendixson theorem, Describing function analysis.

Lyapunov theory for autonomous and non-autonomous systems, Attractors and Basins, Poincare maps.

Nonlinear control system design: Sliding control, Basics of Differential geometry, feedback linearization, single- input and multi-input cases.

Introduction to Chaos, Bifurcations, Hamiltonian Systems.

Cases of Mechanisms, Robotics.

Text Books

1.	*Christopher M Kellett and Philipp Braun, Introduction to Nonlinear Control: Stability, Control Design, and Estimation, Princeton University Press, 2023.*
2.	*A.S.A. Johnson, K.M. Madden, and A.A. Sahin, Discovering Discrete Dynamical Systems, Mathematical Association of America, 2017.*
3.	*Meiss, J.D., Differential Dynamical Systems, SIAM, 2007*
4.	*Jean-Jacques E. Slotine, Applied Nonlinear Control, Prentice Hall Englewood Cliffs, New Jersey, 1991.*

References

1.	*Strogatz, S. H., Nonlinear Dynamics and Chaos, with Applications to Physics, Biology, Chemistry and Engineering, 3rd Edition, CRC Press, 2024.*
2.	*Jitendra R Raol, Ramakalyan Ayyagari, Control Systems: Classical, Modern, and AI-Based Approaches, CRC Press (Taylor and Francis), 2019.*
3.	*Vidyasagar.M, Nonlinear System Analysis, 2nd Edition, SIAM, 2002.*
4.	*D. Hilbert and S. Cohn-Vossen, Geometry and the Imagination, Americal Mathematical Society, 1991.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Differentiate between linear and nonlinear systems and their behaviour
CO2	Apply various graphical and analytical tools to describe and analyze nonlinear systems
CO3	Understand Lyapunov theory
CO4	Learn a range of controller design techniques suitable for nonlinear control systems

Course Code	**:**	**IC632**
Course Title	**:**	**Robot Dynamics and Control**
Number of Credits	**:**	3
Course Type	**:**	PE
Prerequisites	**:**	Robotics in Industrial Automation, Control Systems
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessments	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLOs)

CLO1	To understand the assignment of reference frames to Robots.
CLO2	To study the Dynamic Modelling of Robots and its properties.
CLO3	To design various Controllers specifying the performance requirements of the Robot.
CLO4	To analyse the Stability of the Robot with the designed Controllers.

Course Content:

Fundamentals of Robotics: Prismatic and Rotary Joints, Wrists Design, End Effectors, Actuators, Mathematical Representation of Robots, Position and Orientation, Homogeneous Transformation, Degrees-of-Freedom, Denavit-Hartenberg (D-H) Parameters, Forward Kinematics, Inverse Kinematics, Linear and Angular Velocities, Manipulator Jacobian, Wrist and Arm Singularity, Static Force Analysis.

Robot Dynamics: Acceleration of Rigid Body, Linear Acceleration, Angular Acceleration, Lagrange-Euler Method, Newton-Euler Method, Robotic Manipulator Dynamics in Cartesian Space, State-Space Model, Properties of Robot Dynamic Equations, Consideration of Non-Rigid Body Effects, Trajectory Generation, Illustration on 2-DOF Robotic Manipulator.

Robot Motion Control: Feedback Control System, Stabilization and Trajectory Tracking Problems, Control of Second-Order Systems, Modeling and Control of a single Joint, Manipulator Control Problem, Lyapunov Stability Analysis, Force Control of Robotic Manipulator, Design of Adaptive and Robust Controllers, Illustrative Examples.

Text Books

1.	*A. Ghoshal, "Robotics: Fundamental Concepts and Analysis", Oxford University Press, 2010*
2.	*R. K. Mittal and I. J Nagrath, "Robotics and Control", Tata McGraw Hill (2003)*
3.	*J. J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education, 2022*
4.	*J.-J. E. Slotine, "Applied Non-Linear Control", Prentice Hall, 1991*

References

1.	*R. M. Murray, Z. Li, and S. S. Sastry, "A Mathematical Introduction to Robotic Manipulation", CRC Press, 2017*
2.	*M. W. Spong and M. Vidyasagar, "Robot Dynamics and Control", John Wiley* and Sons *(2008)*
3.	*R. D. Klafter, T. A. Chmielewski and M. Negin, "Robotic Engineering: An Integrated Approach", Prentice Hall, 1989*
4.	*H. K. Khalil, "Nonlinear Systems", Prentice Hall (1991)*

Course Outcomes (COs)

At the end of the course, the Students should be able to:

CO1	Explain the basic concepts of Mathematical Representation of Robot.
CO2	Understand the Robot Dynamics and its properties.
CO3	Design various Controllers for Trajectory Tracking Problem of Robot.
CO4	Analyze the Stability of Robot Motion Control System.

Course Code	**:**	**IC633**
Course Title	**:**	**Condition Monitoring: Industrial Practices**
Number of Credits	**:**	3
Course Type	**:**	PE
Credits / Contact Hours	**:**	3 / 42 hours
Course Assessments	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLOs)

CLO1	To impart knowledge about the significance of condition monitoring: Industrial Practices.
CLO2	To familiarize the students with various sensors and mechanisms used for condition monitoring.
CLO3	To impart knowledge about communication, networking, and emerging technologies used for condition monitoring.
CLO4	To familiarize the students with the industrial practices of lean

Course Content:

Introduction: Motivation for condition monitoring, Historical overview – Reactive Maintenance, Scheduled Maintenance, Condition Based Preventive Maintenance, Predictive Maintenance and Digital Twin. Maintenance Principles, functions, objectives, maintenance strategies, Condition Based Maintenance, Failure Mode, Effect and Critical Analysis (FMECA), Methods of machine fault identification, and its diagnosis.

Sensors and Signal acquisition for condition monitoring, Instrumentation, Data Acquisition, Vibration Monitoring of Rotating Machinery, Motor Current Signature Analysis, Wear Debris and Oil Analysis, NDT – Eddy Current Testing, Magnetic Particle Inspection (MPI), Dye Penetration, Ultrasonics, Acoustic Emission and its applications.

Communication, Networking: Globalization and Emerging Issues, The Fourth Revolution, Introduction to RFID Technology - General Block diagram, and its application for inventory control and supply chain management, Wireless Network Protocols – Bluetooth, WiFi, Zigbee, 5G, NFC, RFID Sensors, Smart and Connected Business Perspective.

Introduction to Smart Factories, Digital Twin, Applications in Condition Monitoring, Self-Sustainability – Role of Energy Harvesting Techniques. Comparison of Wired and Wireless Condition Monitoring, Intelligent Condition Monitoring: Predictive Maintenance, Machine Learning and Data Analytics, and Artificial Intelligence.

Practices of Lean -5 Principles of Lean, Kano Model, Inventory Management – Rock Boat/River Analogy, 5S Methodology, Muda, Muri and Mura, SMED: Gantt Chart, Gemba.

Case study 1 – Machine Fault Diagnosis using Vibration analysis (Wired sensing).
Case study 2 – Crack characterization of metallic structures using RFID Sensor (Wireless sensing).

Text Books

1.	*Plant Maintenance and Reliability Engineering- Prof. N.V.S.Raju, Sengage Learning India Publications, 2011*
2.	*Machinery Condition Monitoring: Principles and Practices, A. R. Mohanty, CRC Press, 2014*
3.	*Amiya Ranjan Mohanty, Machinery Condition Monitoring Principles and Practices, CRC press, Taylor and Francis, 2017.*
4.	*Philip Holt, The Simplicity of Lean: Defeating Complexity, Delivering Excellence, 2019.*

Course Outcomes (COs)

At the end of the course, the students will be

CO1	Familiar with condition monitoring principles and techniques to optimize equipment performance and reliability.
CO2	Able to Implement/deploy effective condition-based maintenance programs to prevent equipment failures and reduce downtime.
CO3	Leverage IoT technologies for real-time monitoring, data collection, and predictive analytics.
CO4	Able to Apply lean manufacturing principles to enhance operational efficiency and reduce waste in maintenance processes.

Course Code	:	**IC634**
Course Title	:	**Modern Optimization Techniques and Algorithms**
Type of Course	:	PE/OE (3 Credits)
Prerequisites	:	MAIR 623 courses
Credits / Contact Hours	:	3 / 42 hours
Assessment Methods	:	Continuous Assessments (3), End Assessment (1)

Course Learning Objectives (CLO)

CLO1	To introduce and elaborate the field of optimization and applications in dynamical systems and engineering.
CLO2	To gain understanding in the methods, both classical and modern, of obtaining optimal solutions under various conditions.
CLO3	To estimate the size of search space in which solutions are sought and appreciate the fundamentals of complex systems.
CLO4	To devise algorithmic optimal solutions via known methods such as Dynamic Programming, and explore modern paradigms such as reinforcement learning for solving a wider class of large-scale real-world problems

Course Content:

Introduction – OR Models, Basic modelling with Linear Programming and its variants, Deterministic Dynamic Programming, Decision Analysis and Games, Markovian Decision Processes, Curse of Dimensionality, Heuristic Methods, e.g., GA, PSO etc.

Online learning – Adaptive learning, spanning lookup tables, parametric and nonparametric models (including neural networks), The Reinforcement Learning Problem.

Derivative-based stochastic optimization – stochastic gradient methods, Step-size policies and *optimal* policies; Derivative-free stochastic optimization – Multi-Armed Bandit Problem and classes of policies applied to this broad problem class.

State-dependent problems – Modelling general dynamic problems, e.g., energy systems, transportation systems, healthcare systems, as sequential decision problems, Designing policies for a given problem.

Approximate Dynamic Programming – Policy function approximations and policy search, Methods for performing search over tunable parameters: numerical derivatives, backpropagation, and the policy-gradient method.

Cost function approximations – Parameterized optimization models widely used in industry on an ad-hoc basis, Applications and Case Studies.

Text Books

1.	*Hamdy A Taha, Operations Research: An Introduction, 9/e, Pearson, 2012.*
2.	*Richard Sutton, A.G. Barto, Reinforcement Learning: An Introduction, 2/e, MIT Press, 2018 (available as a free download).*
3.	*Warren B Powell, Reinforcement Learning and Stochastic Optimization, John Wiley and Sons, 2022.*
4.	*Resources webpage on sequential decision analytics: https://tinyurl. com/sdalinks/*

Reference Books

1.	*D. Bertsekas, Dynamic Programming and Optimal Control, vols. 1 and 2, Athena Scientific, 2012*
2.	*Warren B. Powell, Sequential Decision Analytics and Modeling, NOW Publishing, Boston, MA, 2022, https://tinyurl.com/sdamodeling/ (available as a free download).*
3.	*Paul J Nahin, When Least is Best, Princeton Univ. Press, 2004.*

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Model engineering problems as computational optimization problems.
CO2	Understand the curse of dimensionality and need for heuristics in optimization in terms of Genetic Algorithms and the like.
CO3	Cast engineering design as solution to dynamic optimization problems modelled in learning paradigms.
CO4	Make meaningful objective functions for algorithmically arriving at optimal solutions.