CONSTRUCTION AND MAINTENANCE OF HYDROPOWER PLANTS
ENME 465

Lecture	**: 3**	**Year : IV**
Tutorial	**: 2**	**Part : II**
Practical	**: 1**	

Course Objectives:

The objective of this course is to introduce inspection, troubleshooting, maintenance and repair of hydro-mechanical components used in hydropower plants. It covers maintenance types, tools and safety, as well as the maintenance of gates, valves, penstocks, trash racks, hoisting systems, auxiliary mechanical systems and surface treatment, with an emphasis on failure analysis and preventive maintenance.

1 Introduction (5 hours)

- 1.1 Classification of hydromechanical components
  - 1.1.1 Intake structures
  - 1.1.2 Gates (Radial, vertical lift, sluice)
  - 1.1.3 Valves (Penstock protection valve, main inlet valve, butterfly, spherical, needle)
  - 1.1.4 Penstocks and drain pipelines
  - 1.1.5 Trash racks and screens
- 1.2 Types of maintenance: Breakdown, preventive, predictive and reliability-centered maintenance
- 1.3 Maintenance planning and scheduling
- 1.4 Application of computerized maintenance management systems (CMMS)

2 Tools and Safety Management in Hydropower Plant (6 hours)

- 2.1 Measuring and monitoring devices
- 2.2 Mechanical workshop and equipment
- 2.3 Material handling and equipment
- 2.4 Common HM Spare parts in a hydropower plant (Hoisting, seals, bearings, sensors, nut bolts)
- 2.5 Safety procedures in maintenance work
- 2.6 Emergency response planning (Flood, safe gate operation, fault)

3 Condition Monitoring and Failure Analysis (6 hours)

- 3.1 Inspection: Intervals, inspectors, inspection reports and card system
- 3.2 Condition monitoring: Introduction and techniques
- 3.3 Non-destructive testing (NDT)
  - 3.3.1 Liquid penetrant testing

3.3.2 Magnetic particles testing
3.3.3 Ultrasonic testing
3.3.4 Radiographic testing

3.4 Vibration analysis
3.5 Corrosion monitoring
3.6 Structural health monitoring systems
3.7 SCADA monitoring
3.8 Types of failures
3.8.1 Mechanical failure
3.8.2 Hydraulic failure
3.8.3 Structural failure
3.8.4 Common failure modes: Cavitation, corrosion and erosion, fatigue cracking, seal failure and leakage

4 Maintenance and Repair of Gates and Hoisting Systems (6 hours)

4.1 Types of gates: Radial, vertical lift, sluice
4.2 Common issues:
4.2.1 Misalignment
4.2.2 Seal damage
4.2.3 Corrosion
4.3 Repair methods
4.3.1 Welding and resurfacing
4.3.2 Seal replacement
4.3.3 Structural strengthening
4.4 Maintenance of hoisting mechanisms: Rope drum, hydraulic hoists and lubrication systems

5 Overhauling of Pelton, Francis and Kaplan Turbine (8 hours)

5.1 Planning and preparation
5.2 Shutdown and dismantling
5.3 Inspection and condition assessment handling
5.4 Repair and refurbishment
5.5 Assembly procedure
5.6 Alignment, balancing and installation
5.7 Testing and commissioning
5.8 Reporting

6 Maintenance and Repair of Valves (4 hours)

6.1 Valve operation and control systems
6.2 Common failures
6.2.1 Leakage
6.2.2 Cavitation damage

        6.2.3 Actuator malfunction
    6.3 Repair techniques
        6.3.1 Seat re-machining
        6.3.2 Seal replacement
        6.3.3 Actuator repair

7 Maintenance and Repair of Miscellaneous Systems (6 hours)

7.1 Bearings and couplings: Inspection, failure modes and maintenance
7.2 Penstock: Inspection, failure modes and repair methods
7.3 Trash rack and screening system: Repair and replacement strategies
7.4 Flushing system: Failure modes and maintenance

8 Corrosion Protection and Surface Treatment (4 hours)

8.1 Types of corrosion in hydropower systems
8.2 Protective coatings and linings
8.3 Cathodic protection
8.4 Maintenance of coatings
8.5 Coating techniques on the runner

Tutorial (30 hours)

1. Performing root cause analysis (RCA) on documented hydropower failures involving cavitation, fatigue cracking and seal leakages
2. Evaluating retrofitting and rehabilitation strategies for aging hydropower infrastructure through technical case studies
3. Preparing detailed inspection reports and maintenance card systems for gates, valves and auxiliary mechanical components
4. Formulating step-by-step shutdown and dismantling procedures for the overhauling of Pelton and Francis turbines
5. Calculating necessary tolerances and alignment parameters for turbine assembly, balancing and installation

Practical (15 hours)

1. Executing non-destructive testing (NDT) techniques including ultrasonic, magnetic particle and liquid penetrant testing on structural welds
2. Conducting vibration monitoring and spectral analysis to identify mechanical imbalances and bearing faults in rotating machinery
3. Measuring corrosion rates and assessing the integrity of surface treatments using monitoring probes and thickness gauges
4. Operating structural health monitoring (SHM) devices to assess the stability of penstock saddle supports and anchor blocks
5. Demonstrating turbine runner balancing and alignment techniques during a simulated overhauling and refurbishment exercise
6. Applying various surface treatment techniques and protective linings to components prone to silt erosion and cavitation

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	5	8
2	6	8
3	6	8
4	6	8
5	8	10
6	4	6
7	6	8
8	4	4
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Department of Electricity Development. (2017). Maintenance and repair guidelines for hydropower plants. Government of Nepal.
2. Pandey, R., Senthil Kumar, R. (2017). Fundamentals of operation and maintenance of hydropower plants. PHI Learning.
3. Palmer, R. D. (1999). Maintenance planning and scheduling handbook. McGraw-Hill Education.
4. Gulliver, J. S., Arndt, R. E. A. (1991). Hydropower engineering handbook. McGraw-Hill Education.
5. Novak, P., Moffat, A. I. B., Nalluri, C., Narayanan, R. (2007). Hydropower plants and turbines. Taylor & Francis.
6. Pabla, A. S. (2011). Operation and maintenance of power plants. McGraw-Hill Education.
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ENERGY AUDIT OF THERMAL SYSTEM
ENME 466

Lecture : 3 | **Year : IV**
Tutorial : 2 | **Part : II**
Practical : 1

Course Objectives:
The objective of this course is to provide knowledge regarding the energy efficiency improvement opportunities in thermal equipment's. The course covers various methods of energy auditing techniques and energy efficiency management delivered through the lectures, practical demonstrations and on the site case studies. After completion of the course, students will be able to use knowledge and hands on experience and skills about energy auditing and managing the energy demand of thermal equipment's.

1 Fuel, Combustion and Thermal Equipment (4 hours)

1.1 Introduction to fuel and types
1.2 Combustion and calculation of stoichiometric air, draft system
1.3 Thermal equipment's used in industrial sector, residential sector and other sectors

2 Furnaces (8 hours)

2.1 Types and classification of furnaces
2.2 Performance evaluation of furnace: Direct and indirect method, Sankey diagram, stored heat loss, wall losses, material handling losses, cooling media losses, radiation (Opening) losses, waste-gas losses, air infiltration
2.3 General fuel economy measures in furnaces, energy conservation (ENCON) opportunities
2.4 Energy conservation in furnaces: Complete combustion with minimum excess air, proper heat distribution, maintaining optimum operating temperature, prevention of heat loss through openings, control of furnace draft, optimum capacity utilization, waste heat recovery from furnace flue gases, minimizing wall losses, use of ceramic coatings and fish bone diagram for energy conservation in furnaces
2.5 Data collection format for furnace performance assessment

3 Boilers (8 hours)

3.1 Fuel and combustion
3.2 Types of boilers
3.3 Performance evaluation: Direct and indirect method
3.4 Factors affecting boiler performance, boiler breakdown and boiler water treatment

3.5 Energy Conservation (ENCON) opportunities
3.6 Heat exchanger, economizer
3.7 Data collection format for boiler performance assessment

4 Steam Distribution System (8 hours)

4.1 Properties of steam
4.2 Steam pipe sizing, proper selection, operation and maintenance of steam traps
4.3 Performance assessment methods for steam traps, steam leakages
4.4 Optimum insulation, economic thickness of insulation
4.5 Steam utilization, condensate and flash steam recovery system
4.6 Steam balance and energy saving opportunities

5 Heat Recovery Systems (8 hours)

5.1 Sources of waste heat, guidelines to identify waste heat, grading of waste heat,
5.2 Feasibility study of waste heat recovery, gas to gas heat recovery, rotary generators, heat pipes, gas to liquid heat recovery, waste heat boilers

6 Cogeneration (5 hours)

6.1 Definition and need, basics of thermodynamic cycles
6.2 Classification, merits and demerits of cogeneration systems: Steam turbine, gas turbine, reciprocating engine
6.3 Important technical parameters for cogeneration, heat to power ratio, operating strategies, typical cogeneration performance parameters.
6.4 Tri-generation or combined cooling, heat and power (CCHP)

7 Final Audit Report Preparation (4 hours)

7.1 Methodology for preliminary and detailed energy audit of thermal components
7.2 Energy flow diagram, measuring instruments used for energy audit of thermal components
7.3 Checklist for energy auditors
7.4 Energy audit report preparation for selected case

Tutorial (30 hours)

1. Case studies of various type of furnaces in several industries in Nepal and around the world
2. Case studies of small, medium and large scale boilers
3. Engineering a more efficient future for dairy with steam distribution system
4. Case studies of various heat recovery system in Nepalese's enterprises
5. Case studies in co-generation and regeneration.

Practical **(15 hours)**

1. Study and performance observance of following thermal equipment:
   i. Digital concrete moisture meter
   ii. Digital light meter
   iii. Gas leak detector
   iv. Gas combustion analyzer
   v. Digital pressure gauge
   vi. Thermal image camera
   vii. Blower door and accessories
   viii. Cooking device energy efficiency demonstration unit
   ix. Thermometers: Contact and non-contact type
   x. Air and water flow meters
2. Performance analysis of Boiler
3. Performance Analysis of Furnaces

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	4	6
2	8	15
3	8	15
4	8	8
5	8	8
6	5	4
7	4	4
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Abbi, Y. P., Jain, S. (2006). Handbook of energy audit and environment management. TERI Press.
2. Polimeros, G. (1981). Energy cogeneration handbook (Latest Edition). Industrial Press.
3. Threlkeld, J. L. (1970). Thermal environmental engineering (Latest Edition). Prentice Hall.
4. Trinks, W., Mawhinney, M. H., Shannon, R. A., Reed, R. J., & Garvey, J. R. (2003). Industrial furnaces. John Wiley & Sons.
5. Turner, W. C. (2007). Energy management handbook. Fairmont Press.
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BUILDING SERVICES AND ENERGY MANAGEMENT
ENME 467

Lecture	**: 3**	**Year : IV**
Tutorial	**: 2**	**Part : II**
Practical	**: 1**	

Course Objectives:
The objective of this course is to familiarize students with basics of services requirements in building construction including fire protection system, electrical systems, transportation and other mechanical equipment, along with their design, operation and layout in different types of buildings.

1 Introduction to Building Services (5 hours)

- 1.1 Definition and scope of building services
- 1.2 Classification of building services: Electrical, mechanical, plumbing, fire safety
- 1.3 Building types and service requirements: Residential, commercial and industrial
- 1.4 Functional requirements: Safety, hygiene, comfort, sustainability

2 Electrical Services (8 hours)

- 2.1 Electrical load estimation: Connected load, maximum demand, demand factor and diversity factor
- 2.2 Power distribution systems: Single-phase and three-phase systems
- 2.3 Wiring systems and layout design: Residential buildings, commercial buildings, industrial buildings
- 2.4 Lighting systems: LED, fluorescent, efficiency concepts
- 2.5 Backup power systems: Generator, ups systems

3 Mechanical Services (8 hours)

- 3.1 Lift: Definition, types of lifts, design considerations, location, sizes, component parts
- 3.2 Elevators and escalators: Different types of elevators and escalators, freight elevators, passenger elevators, hospital elevators, uses of different types of elevators and escalators
- 3.3 Air conditioning systems: Window, split, packaged units
- 3.4 Ventilation systems: Natural ventilation, mechanical ventilation
- 3.5 Pumps and basic mechanical utility systems

4 Plumbing Services (8 hours)

4.1 Water supply systems: Sources, distribution, storage tanks
4.2 Pipe systems: Materials and layout principles
4.3 Drainage systems: Sanitary drainage, storm water drainage
4.4 Sewage disposal systems
4.5 Rainwater harvesting
4.6 Maintenance and basic design principles

5 Fire Safety Systems (8 hours)

5.1 Fire fundamentals: Fire triangle, classification of fire
5.2 Fire protection systems: Fire extinguishers, hydrant systems, sprinkler systems
5.3 Fire detection systems: Smoke detectors, heat detectors, alarm systems
5.4 Smoke control and evacuation planning
5.5 Fire safety codes and regulations

6 Energy Management (8 hours)

6.1 Energy management in buildings
6.2 Energy audit process and reporting
6.3 Building automation systems (BAS)
6.4 Building management system (BMS)
6.5 Integration of renewable sources: Solar PV, solar water heating
6.6 Applications of sensors and smart devices to save energy

Tutorial (30 hours)

1. Identify building service components in a given building plan (Residential and commercial)
2. Design an electrical layout drawing for a small building
3. Lighting design calculation (Lux method) for a room/classroom
4. Calculation of number of lifts for a multi-storey building
5. Ventilation rate calculation for a room
6. Pipe sizing calculation for water distribution system
7. Design of fire alarm system layout for a floor of commercial building
8. Case study of fire safety failure and analysis
9. Preparation of basic energy audit report (Sample building)
10. Use of commercial software for Building Management System (BMS)

Practical (15 hours)

1. Evacuation path marking on building plan
2. Comparison of energy consumption between led and fluorescent lamps by Illumination (Lux) calculation of rooms/classroom
3. To use smoke detection system and perform evacuation
4. Case preparation for energy audit of residential building

5. Field study of commercial building
6. Case study on components and features of building services in industrial building

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	5	6
2	8	12
3	8	12
4	8	12
5	8	10
6	8	8
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. ASHRAE. (2021). ASHRAE handbook: Fundamentals. ASHRAE.
2. Chadderton, D. V. (1995). Building services engineering (Latest Edition). Routledge.
3. Hall, F., Greeno, R. (2007). Building services handbook. Butterworth-Heinemann.
4. Hassan, G. (1996). Building services (Latest Edition). Palgrave Macmillan.
5. Moss, K. (2006). Energy management in buildings. Routledge.
6. Tymkow, P., Tassou, S., Kolokotroni, M., Jouhara, H. (2013). Building services design for energy efficient buildings. Routledge.

INDUSTRIAL AUTOMATION
ENME 468

Lecture : 3 **Year : IV**
Tutorial : 2 **Part : II**
Practical : 1

Course Objectives:
The objective of this course is to provide students with the knowledge and skills required for industrial automation through the study of Industry 4.0 concepts, industrial sensors and actuators, fluid power systems, and PLC-based control. Upon completion, students will be able to apply CNC technology, flexible manufacturing systems (FMS), and computer-integrated manufacturing (CIM) to design, operate, and optimize automated manufacturing and industrial production systems.

1 Introduction (4 hours)

1.1 Definition, scope and significance of industrial automation
1.2 Types of automation: Fixed, programmable and flexible automation systems
1.3 Levels of automation, migration framework
1.4 Industrial Control Systems: Continuous versus discrete control systems, Batch process control, open loop versus closed-loop control overview, feedback, feedforward and cascade control strategies
1.5 Industry 4.0: Digitization, industrial internet of things (IIoT) and smart manufacturing
1.6 Hydraulic and pneumatic systems: Working, types, components

2 Control System Components (8 hours)

2.1 Sensors and transducers: Proximity sensors, limit switches, displacement sensors, temperature sensors, vision systems for machine inspection (Cameras, image acquisition, pattern recognition)
2.2 Electric actuators
2.2.1 DC motors, stepper motors, servo motors: Comparison and selection criteria
2.2.2 Variable frequency drives (VFDs) and motor control centers
2.3 Hydraulic actuators
2.3.1 Types of hydraulic actuators: Hydraulic cylinders (Single-acting, double-acting), hydraulic motors
2.3.2 Hydraulic power pack: Pump types (Gear, vane, piston), reservoir, relief valves
2.3.3 Hydraulic control valves: Directional control valves (DCVs), pressure control valves, flow control valves

2.3.4 Hydraulic circuit schematic symbols (ISO 1219) and reading/drawing hydraulic schematics

2.3.5 Hydraulic circuit design: Regenerative circuit, meter-in/meter-out circuits, accumulator circuits

2.4 Pneumatic actuators

2.4.1 Types of pneumatic actuators: Single-acting and double-acting cylinders, rotary actuators

2.4.2 Pneumatic power supply: Compressors, FRL unit (Filter-Regulator-Lubricator), air preparation

2.4.3 Pneumatic control valves: DCVs (2/2, 3/2, 4/2, 5/2 valves), flow control and pressure valves

2.4.4 Pneumatic circuit schematic symbols (ISO 1219) and reading/drawing pneumatic schematics

2.5 Electro-pneumatic circuits: Integration of solenoid valves with PLC control Comparison of hydraulic versus pneumatic systems: Advantages, limitations and selection criteria

3 Programmable Logic Controllers (PLCs) (8 hours)

3.1 Advanced PLC architecture

3.1.1 PLC hardware: CPU, I/O modules, power supply, memory organization

3.1.2 Input/output addressing and I/O configuration: Digital, analog and specialty modules

3.1.3 Scan cycle and execution modes; Determinism in real-time control

3.2 IEC 61131-3 Programming Languages

3.2.1 Ladder Diagram (LD): Advanced rungs, functional blocks and structured programs

3.2.2 Structured Text (T): Syntax, data types, control structures

3.2.3 Function Block Diagram (FBD): Data flow, standard and custom function blocks

3.2.4 Sequential Function Chart (SFC/Grafcet): Steps, transitions, actions and divergence

3.2.5 Instruction List (IL): Overview and legacy usage

3.3 Industrial communication and Networking

3.4 SCADA and HMI Systems: SCADA architecture, HMI design principles, remote monitoring and control, cybersecurity considerations in industrial control systems

4 CNC Technology and Part Programming (7 hours)

4.1 Numerical control fundamentals: Evolution from NC to CNC to DNC, classification of CNC systems

4.2 CNC machine tool components: Axes, drives, feedback devices and controller

- 4.3 Coordinate systems and reference points: Machine zero, work zero, tool offset
- 4.4 Interpolation: Linear circular and helical
- 4.5 Manual part programming: G-code and M-code, worked examples (turning and milling programs)
- 4.6 Computer assisted part programming: Automatically programmed tool (APT) language, toolpath generation from 3D models, Post-processing
- 4.7 Multi-axis Machine: 4-axis and 5-axis CNC machining, Introduction to 6-axis robotic machining and hybrid manufacturing cell

5 Flexible Manufacturing and Computer-Integrated Manufacturing (6 hours)

- 5.1 Automated Material Handling
  - 5.1.1 Material handling: Ergonomics and flow optimization
  - 5.1.2 Conveyor systems: Belt, roller, overhead and power-and-free conveyors
  - 5.1.3 Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs)
- 5.2 Flexible Manufacturing Systems (FMS)
  - 5.2.1 FMS definition, components and classification
  - 5.2.2 Workstations, tool management
  - 5.2.3 FMS control and scheduling: routing, dispatching rules and simulation
  - 5.2.4 Benefits and economic justification of FMS
- 5.3 Computer-Integrated Manufacturing (CIM)
  - 5.3.1 CIM framework: Integration of design, planning and production
  - 5.3.2 Computer-Aided Process Planning (CAPP)
  - 5.3.3 Enterprise Resource Planning (ERP)

6 Artificial Intelligence and Machine Learning in Automation (6 hours)

- 6.1 Artificial Intelligence: Foundation, History, Intelligent Agents
- 6.2 AI Techniques: Machine Learning (ML), Deep Learning (DL), Computer Vision (CV)
- 6.3 Industry Relevant Algorithms
- 6.4 AI in industrial maintenance, control and optimization
- 6.5 Case Studies

7 Simulation, Safety and System Integration (6 hours)

- 7.1 System Simulation and Digital Manufacturing: Modeling approaches, simulation software for production systems
- 7.2 Virtual commissioning: concept, workflow and benefits for automation projects
- 7.3 Digital twins and its application in industry

7.4 Industrial Safety: Hazard Identification and risk assessment, functional safety standards (IEC 62061 and ISO 13849), safety-rated PLCs and safety relays, Physical guarding, Lockout/Tagout (LOTO) procedures

7.5 Human-Machine Interaction deign for operator effectiveness and safety, collaborative robots (cobots), standards (ISO/TS 15066), speed and force limiting and workspace sharing, Alarm management (IEC 62682 principles)

Tutorial **(30 hours)**

1. Hydraulic and Pneumatic circuit analysis: Calculation of cylinder forces, sizing of cylinders, flow rates, pump power and actuator speeds, calculation of air consumption and compressor sizing
2. PLC programming exercises: Design of ladder diagrams and SFC programs for multi-step sequential control problems
3. PLC-based PID controller implementation
4. CNC part programming: Manual G-code program for turning and milling operations with given part geometry.
5. CAPP exercise: Developing process plans using variant and generative approaches for sample components.
6. Fundamentals of Python Programming and implementation of basic ML algorithms

Practical **(15 hours)**

1. PLC programming exercises (Ladder Logic)
2. Advanced PLC programming: Analog I/O handling and PID control implementation on a physical or simulated process
3. Pneumatic and electro-pneumatic circuit design and commissioning using FluidSim software and/or physical trainer kits
4. CNC machine tool operation: Writing and running a part program for a simple component (turning or milling)

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	4	6
2	8	12
3	8	10
4	7	8
5	6	8
6	6	8
7	6	8
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Groover, M. P. (2019). Automation, production systems and computer-integrated manufacturing. Pearson.
2. Bolton, W. (2021). Programmable logic controllers. Elsevier.
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OPERATIONS RESEARCH
ENME 470

Lecture	**: 3**	**Year : IV**
Tutorial	**: 2**	**Part : II**
Practical	**: 1**	

Course Objectives:

The objective of this course is to provide foundational knowledge of operations research, enabling students to manage and analyze data, apply forecasting techniques and use optimization models in areas such as production, transportation and finance. It also equips students with skills in inventory management, simulation and systems modeling to support effective decision-making under risk and uncertainty using relevant software tools.

1 Introduction (4 hours)

1.1 Operations research: Historical background and applications
1.2 Model types, characteristics and benefits
1.3 Mathematical modeling
1.4 Problem solving process
1.5 Interpretation and use of model results
1.6 Interface between data and model
1.7 Applications of data management and analysis
1.8 Data storage and retrieval
1.9 Use of spreadsheet in data management

2 Optimization (12 hours)

2.1 Limited resources and introduction to optimization
2.2 Characteristics of optimization problems
  2.2.1 Identification of decision variables
  2.2.2 Objective functions and constraints
  2.2.3 Formulation of mathematical model
2.3 Linear programming
  2.3.1 Graphical method, simplex method, computer model
  2.3.2 Steps for formulating linear models
  2.3.3 Solving optimization problems in spreadsheet environment
2.4 Special conditions: Degeneracy, unbounded, infeasible solutions
2.5 Sensitivity analysis: Shadow prices and reduced costs concepts
2.6 Modeling linear programming problems in spreadsheets
2.7 Network modeling and integer programming
2.8 Goal programming and multiple objective optimization
2.9 Non-linear programming

3 Regression and Time Series Analysis (10 hours)

3.1 Fundamental concepts and theories
3.2 Simple regression analysis
3.3 Multiple regression analysis and multi-collinearity
3.4 Polynomial regression
3.5 Time series data: Stationary, non-stationary, seasonal data
3.6 Analysis of stationary models, seasonality models and trend models
3.7 Using CB-predictor for time series analysis

4 Decision Analysis and Multi-criteria Decision Analysis (5 hours)

4.1 Characteristics of decision problems
4.2 Construction of payoff and regret matrix
4.3 Non-probabilistic decision rules: Maximax, maximin, minimax regret,
4.4 Probabilistic decision rules: Expected monetary value, expected opportunity loss
4.5 Decision tree
4.6 Multi-criteria decision analysis (MCDA)
4.7 Theory of games: Pure and mixed strategies, principles of dominance

5 Inventory Control and Queuing Theory (5 hours)

5.1 Inventory control models
 5.1.1 Types of inventories
 5.1.2 EOQ (Economic order quantity) model
 5.1.3 Economic order quantity with and without shortages
 5.1.4 Quantity discount models
 5.1.5 Probabilistic inventory models
5.2 Queuing theory
 5.2.1 Basic components of a queuing system
 5.2.2 Kenel Notation of queuing model
 5.2.3 Steady-state solution of Markovian queuing models
 5.2.4 Economic analysis of queuing system

6 Risk and Uncertainty Analysis (9 hours)

6.1 Monte Carlo simulation
6.2 Applications of Monte Carlo simulation
6.3 Different probability distributions
6.4 Building simulation models with CRYSTAL BALL
6.5 Decision and risk analysis
6.6 Application of decision and risk analysis
6.7 Multi-criteria decision analysis (MCDA)

Tutorial (30 hours)

1. Exercises on basic and advanced functions in spreadsheets

2. Problems related to linear programming and developing models in spreadsheet
3. Problems related to network models and solving it in in spreadsheet
4. Problems related to multi objective programming and solving it in spreadsheet
5. Exercises related to regression analysis in spreadsheets
6. Exercises related to time series analysis in spreadsheets
7. Problems related to risk analysis and solving it in in spreadsheet using Monte Carlo simulation
8. Exercises related to decision analysis in spreadsheets

Practical **(15 hours)**

1. Development of spreadsheet model for optimization problem
2. Development of spreadsheet model for regression and time series problem
3. Development of spreadsheet model for risk analysis and uncertainty analysis
4. Development of spreadsheet model for decision analysis problems
5. Case studies and group presentation on mathematical formulation of real-world problems and solutions through spreadsheet modeling

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1, 2	16	24
3	10	12
4, 5	10	12
6	9	12
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Camm, J. D., Evans, J. R. (2000). Management science & decision technology. South-Western College Publishing.
2. Evans, J. R., Olson, D. L. (1998). Introduction to simulation and risk analysis. (Latest Edition) Prentice Hall.
3. Hillier, F. S., Hillier, M. S., Lieberman, G. J. (2000). Introduction to management science: A modeling and case studies approach with spreadsheets. McGraw-Hill Education.
4. Ragsdale, C. T. (2008). Spreadsheet modeling and decision analysis: A practical introduction to management science. Cengage Learning.
5. Winston, W., Albright, S. C. (2009). Practical management science: Spreadsheet modeling and applications. Cengage Learning.

AIRCRAFT DYNAMICS
ENME 471

Lecture	**: 3**	**Year : IV**
Tutorial	**: 2**	**Part : II**
Practical	**: 1**	

Course Objectives:
The objective of this course is to provide concepts on evaluation of performance, stability, and control characteristics of diverse airborne vehicles. At the end of the course, students will be able to analyze the flight dynamics governing fixed-wing and UAV platforms by applying equations of motion and predict longitudinal, lateral and directional behavior.

1 Fundamentals of Aerodynamics (7 hours)

1.1 Introduction to atmospheric flight mechanics
1.2 Standard atmosphere
1.3 Airfoil fundamentals
1.4 Aerodynamic forces and aerodynamic coefficients
1.5 Lift and drag of bodies
1.6 Induced drag and drag polar
1.7 Low-speed aerodynamics: Thin airfoil theory
1.8 3D aerodynamic lift and drag
1.9 Flow of a compressible fluid

2 Aircraft Performance (10 hours)

2.1 Equations of motion for flight in vertical plane
2.2 Gliding flight
2.3 Level flight performance
2.4 Climbing flight
2.5 Range and endurance: Breguet Range and Endurance Equations, Jet versus Propeller aircraft
2.6 Turning flight: Coordinated turns, load factor and turn radius
2.7 Take-off and landing performance: Ground roll and airborne phases, balanced field length
2.8 Hazards during take-off and landing: Wind shear, microburst phenomena and pilot response

3 Aircraft Static Stability and Control (12 hours)

3.1 Introduction to stability and control
3.2 Longitudinal static stability
3.2.1 Stability criteria

- 3.2.2 Contribution of aircraft components: Wing, tail, canard and fuselage
- 3.2.3 Power effects
- 3.2.4 Stick-fixed neutral point
- 3.2.5 Contribution of aircraft components

3.3 Longitudinal control
- 3.3.1 Elevator effectiveness
- 3.3.2 Elevator angle to trim
- 3.3.3 Elevator hinge moment

3.4 Stick-free stability
- 3.4.1 Trim tabs
- 3.4.2 Stick force gradients

3.5 Directional stability: Contribution of aircraft components and directional control

3.6 Lateral Stability: Contribution of aircraft components and roll control

3.7 Stability in maneuvering flights

4 Dynamic Stability (6 hours)

4.1 Introduction to dynamic response

4.2 Equations of motion

4.3 Forces acting on the airplane

4.4 Longitudinal dynamic modes: Phugoid and short-period motion

4.5 Lateral-directional dynamic modes: Dutch roll and spiral mode

5 Aircraft Design Principles (6 hours)

5.1 Overview of the aircraft design process
- 5.1.1 Mission requirements and constraints
- 5.1.2 Conceptual, preliminary and detailed design phases
- 5.1.3 Role of iteration and trade studies

5.2 Conceptual design parameters
- 5.2.1 Requirements
- 5.2.2 Weight estimation
- 5.2.3 Critical performance parameters
- 5.2.4 Configuration layout
- 5.2.5 Constraint analysis plots
- 5.2.6 Airfoil selection

6 Modern Design Tools and Techniques (4 hours)

6.1 Application of CFD and FEM tools in early-stage design

6.2 Multidisciplinary design optimization (MDO)

6.3 Emerging technologies (Digital Twin, parametric design and surrogate modelling)

Tutorial **(30 hours)**

1. Calculation and modeling of the standard atmosphere to determine pressure, temperature, and density gradients across varying altitudes
2. Decoding and analysis of NACA airfoil geometry to evaluate aerodynamic parameters and their influence on lift and drag
3. Evaluation and prediction of aircraft performance metrics, including range, endurance, flight envelope boundaries, and take-off/landing characteristics
4. Assessment and classification of static stability criteria to differentiate between stable, neutral, and unstable flight configurations
5. Determination and calculation of the neutral point and static stability margins for complex aircraft geometries
6. Analysis and verification of control surface effectiveness, specifically focused on elevator authority and equilibrium trim conditions

Practical **(15 hours)**

1. Analysis and evaluation of airfoil performance characteristics using XFLR5 simulation software
2. Design and development of aircraft models utilizing specialized CAD tools such as XFLR5 and OpenVSP
3. Conceptualization and synthesis of UAV systems based on fundamental aircraft design principles
4. Execution and coordination of collaborative group design projects through the application of advanced software workflows
5. Simulation and quantitative prediction of aircraft flight performance metrics using MATLAB environments

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	7	10
2	10	12
3	12	16
4	6	8
5	6	8
6	4	6
Total	**45**	**60**

* There may be minor deviation in marks distribution.

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2. Etkin, B., Reid, L. D. (1995). Dynamics of flight: Stability and control (). John Wiley & Sons.

3. Mishra, D. P. (2010). Fundamentals of combustion. Prentice Hall of India.
4. Pamadi, B. N. (2004). Performance, stability, dynamics, and control of airplanes. AIAA.
5. Raymer, D. P. (2018). Aircraft design: A conceptual approach. AIAA.
6. Roskam, J. (2003). Airplane flight dynamics and automatic flight controls. DARcorporation.
7. Tewari, A. (2011). Advanced control of aircraft, spacecraft, and rockets. Wiley.