

BASICS OF HYDROPOWER ENGINEERING

ENME 365

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to explore the knowledge on basics of hydropower engineering. It deals with energy scenarios, the hydraulic, hydro-mechanical and electrical components of a hydropower plant, estimation of power, stages of developing a hydropower plant and auxiliary system components and operation.

1 Introduction (6 hours)

- 1.1 Sources of energy
- 1.2 National, regional and global scenario of hydropower
- 1.3 Hydropower development history in Nepal
- 1.4 Challenges in hydropower development
- 1.5 Existing policies of the Nepal government related to hydropower
- 1.6 Typical components of a hydropower plant
- 1.7 Types of hydropower plants based on head and capacity

2 Estimation of Hydropower Project Potential (8 hours)

- 2.1 Layouts of hydropower plants
 - 2.1.1 Run-of-river (ROR)
 - 2.1.2 Peaking run-of-river (PROR)
 - 2.1.3 Storage project
 - 2.1.4 Cascade project
 - 2.1.5 Multi-purpose hydropower project
 - 2.1.6 Pumped storage projects
- 2.2 Processing of hydrological data
 - 2.2.1 Use of extreme and long-term hydrological data
 - 2.2.2 Mass curve and elevation-volume curve
 - 2.2.3 Flow duration curves (FDC)
- 2.3 Measurement of gross head and estimation of net head
- 2.4 Methods of fixing the installed capacity of a hydropower plant
- 2.5 Estimation of power and energy potential
- 2.6 Mean and peak load, load curve, load factor, utilization and diversity factors

- 3 Developing Hydropower Projects (6 hours)**
- 3.1 Stages of hydropower development
 - 3.1.1 Reconnaissance
 - 3.1.2 Prefeasibility
 - 3.1.3 Feasibility studies
 - 3.1.4 Detailed engineering design
 - 3.2 Locating a hydropower station
 - 3.2.1 Water and land availability
 - 3.2.2 Type of power station: Surface and underground
 - 3.2.3 Environmental study
- 4 Hydraulic Components (6 hours)**
- 4.1 Civil components of the hydropower plant
 - 4.2 Operation of reservoirs, dams and barrage
 - 4.3 Intake structure, desilting basin and desander
 - 4.4 Headrace tunnel (HRT), canals and forebay
 - 4.5 Surge tank and types
 - 4.6 Transition connections: Bell mouth, circular to D-shape
 - 4.7 Penstock, expansion joints, steel liner (Vertical shaft)
 - 4.8 Spillway, powerhouse and tailrace
- 5 Hydromechanical Components (6 hours)**
- 5.1 Gates and stoplogs types
 - 5.2 Trash racks and tranquilizer
 - 5.3 Valves: Types and selection
 - 5.4 Turbine: Types, specification and selection
 - 5.5 Governor: Types, selection and operation
- 6 Electrical Components (6 hours)**
- 6.1 Generator: Types, sizing, specification and selection
 - 6.2 Control and monitoring system
 - 6.3 Transmission system components
 - 6.4 Distribution system components
 - 6.5 Transformer: Types, sizing, specification and selection
 - 6.6 Conductor cables: Types, sizing and selection
 - 6.7 Grid synchronization
- 7 Auxiliary Systems and Operations (7 hours)**
- 7.1 High-pressure lubrication system
 - 7.2 Braking and jacking system
 - 7.3 Centralized grease lubrication (CGL) system
 - 7.4 Carbon dust collection system for slip rings

- 7.5 Exciters and brake pads
- 7.6 Cooling water system
- 7.7 Ventilation and air conditioning
- 7.8 Compressed air system
- 7.9 Dewatering and drainage system
- 7.10 Trash rack cleaning system
- 7.11 Hoisting system for gates and stop-logs
- 7.12 Safety systems and devices

Tutorial (30 hours)

1. Analyzing hydrological data to construct FDC for energy estimation
2. Calculating gross and net head while determining the optimal installed capacity for ROR and PROR projects
3. Evaluating energy potential and plant performance using load curves, load factors and diversity factors
4. Assessing hydraulic losses in conduits and analyzing pressure fluctuations in surge shafts and penstocks
5. Selecting appropriate turbine types and governors based on head-discharge characteristics and site requirements
6. Sizing electrical components including generators, transformers and transmission cables for grid synchronization

Practical (15 hours)

1. Review of the hydropower status and policy frameworks of Nepal, South Asia and the global energy market
2. Visit to a hydropower station to document civil, hydro-mechanical and electrical components in operation
3. Develop a pre-feasibility report that integrates technical design, environmental study and cost-benefit analysis

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	Mark distribution*
1	6	8
2	8	10
3	6	8
4	6	8
5	6	8
6	6	8
7	7	10
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Department of Electricity Development. (2018). Guidelines for study of hydropower projects, 2018. Government of Nepal, Ministry of Energy, Water Resources and Irrigation.
2. Mosonyi, E. (1991). Water power development: Vol. 1. Low-head hydropower plants (Latest Edition). Akadémiai Kiadó.
3. Mosonyi, E. (1991). Water power development: Vol. 2. High-head hydropower plants (Latest Edition). Akadémiai Kiadó.
4. Baral, S. (2019). Fundamentals of hydropower engineering. Engineering and Education Services.
5. Nigam, P. S. (1999). Handbook of hydro engineering (Latest Edition). Nem Chand & Sons.
6. Dandekar, M. M., Sharma, K. N. (1991). Water power engineering (Latest Edition). Vikas Publishing House.
7. Novak, P., Moffat, A. I. B., Nalluri, C., Narayanan, R. (2007). Hydraulic structures. Taylor & Francis.
8. Warnick, C. C., Velej, J. F., Associates. (1984). Hydropower engineering (Latest Edition). Prentice Hall.
9. Norwegian University of Science and Technology. (n.d.). Hydropower development series (Vols. 8, 9, 10, 12, 13, 14). NTNU.
10. Chapman, S. J. (2012). Electric machinery fundamentals. McGraw-Hill Education.

ENERGY AUDIT, EFFICIENCY AND MANAGEMENT

ENME 366

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to provide knowledge regarding the in-depth understanding of theory, approaches and practices dealing with various energy intensive processes in buildings and industries and to find out the energy conservation opportunities. The course covers various methods of energy efficiency management and energy auditing techniques delivered through the lectures, practical demonstrations and on the site case studies.

- 1 Introduction to Energy Management (4 hours)**
 - 1.1 Energy scenarios and need for energy management and conservation
 - 1.2 Principles of energy management: Planning, organizing, controlling and leading
 - 1.3 Energy management process: From policy to action plan
 - 1.4 Energy efficiency policies and regulating mechanisms in Nepal
 - 1.5 International practices: UN SDG goal 7

- 2 Fundamental of Energy Efficiency (6 hours)**
 - 2.1 Definition and concept of energy efficiency and energy conservation
 - 2.2 Benefits of energy efficiency: Economic, environmental, social and operational
 - 2.3 Barriers to energy efficiency adoption: Technical, financial, behavioral, regulatory
 - 2.4 Strategies for energy saving: Demand-side management, supply-side efficiency improvement, behavioral and operational improvement
 - 2.5 Energy efficiency guide: Energy star, labeling programs and international standards
 - 2.6 Energy saving measures and potential in different sectors: Industry, building and transport
 - 2.7 Energy efficient and green buildings

- 3 Fundamental of Energy Auditing (6 hours)**
 - 3.1 Definition, objectives and scope of an energy audit

- 3.2 Types of energy audit: Walk through (level I) audit, detailed/diagnosis (Level II) audit, investment grade audit (Level III) audit
- 3.3 Phases of energy audit: Pre-audit (Planning), audit (Data collection and monitoring), post-audit (Analysis and reporting)
- 3.4 Role, responsibilities and code of conduct for an energy auditor
- 3.5 Energy flow diagrams and Sankey diagrams

4 Energy audit procedures and techniques (13 hours)

- 4.1 Data collection and preliminary assessment
 - 4.1.1 Energy consumption pattern study
 - 4.1.2 Occupancy and usage patterns
 - 4.1.3 Architectural evaluation
 - 4.1.4 Operation and management system
 - 4.1.5 Energy sources and usage
 - 4.1.6 Energy control systems
 - 4.1.7 Time-series data collection
 - 4.1.8 Special tests: On-site measurements and diagnostics
- 4.2 Analytical techniques
 - 4.2.1 Incremental cost concept
 - 4.2.2 Mass and energy balance
 - 4.2.3 Inventory of energy inputs and losses
 - 4.2.4 Heat transfer calculations
 - 4.2.5 Electrical load analysis
 - 4.2.6 Energy system simulation
 - 4.2.7 Energy balance sheet
 - 4.2.8 Management information system (MIS)
 - 4.2.9 Energy modeling and optimization
- 4.3 Evaluation of saving opportunities
 - 4.3.1 Estimation of energy savings
 - 4.3.2 Economic analysis
 - 4.3.3 Non-economic factors
 - 4.3.4 Energy conservation opportunities
- 4.4 Energy audit reporting
 - 4.4.1 Importance of energy audit report
 - 4.4.2 Contents of report
 - 4.4.3 Report organization
 - 4.4.4 Presentation techniques
- 4.5 Professional responsibilities of energy auditors
 - 4.5.1 Professional responsibilities
 - 4.5.2 Ethical considerations
 - 4.5.3 Data confidentiality
 - 4.5.4 Compliance with standards

- 4.6 Energy audit checklist
 - 4.6.1 Pre-audit checklist
 - 4.6.2 Audit-phase checklist
 - 4.6.3 Post-audit checklist
 - 4.6.4 Equipment and safety checklist

5 Energy Audit Instruments (6 hours)

- 5.1 Thermal instruments: Flue gas analyzers, thermometers, temperature indicators, infrared thermometers, thermal insulation scanner, thermal-hygrometer, thermal imager and conductivity meter
- 5.2 Mechanical instruments: U-Tube manometer, tachometer, pH meter, ultrasonic flow meter, vis- gauge, anemometer and digital pressure meter
- 5.3 Electrical: Power analyzer, demand analyzer, watt meter, clamp on ampere meter (AC/DC), digital multi-meter and lux-meter

6 Building Energy Audit (6 hours)

- 6.1 Building envelope analysis
 - 6.1.1 Definition of building envelope: Walls, roof, floors, windows and doors
 - 6.1.2 Role of envelope in energy efficiency
 - 6.1.3 Heat transfer mechanisms
 - 6.1.4 Thermal bridging and insulation impact
 - 6.1.5 Airtightness and infiltration
- 6.2 Heat transfer in building components
 - 6.2.1 Walls and roofs (U-value, R-value, thermal mass effects)
 - 6.2.2 Windows and doors (Glazing type, frame material, shading)
 - 6.2.3 Floors and ceilings (Heat gain/loss calculations)
 - 6.2.4 Air leakage (Detection and mitigation)
- 6.3 Building energy simulation
 - 6.3.1 Introduction to building simulation software
 - 6.3.2 Input parameters (Geometry, materials, occupancy, equipment)
 - 6.3.3 Output parameters (Peak load, annual energy consumption)
 - 6.3.4 Case study (Optimizing building design for energy efficiency)
- 6.4 Chilled water storage systems
 - 6.4.1 Principles of chilled water systems for HVAC
 - 6.4.2 Storage sizing and operation
 - 6.4.3 Energy optimization strategies
 - 6.4.4 Integration with building energy management systems
- 6.5 Thermal Insulation
 - 6.5.1 Types of insulation (Walls, roof, floors, pipes)
 - 6.5.2 Thermal conductivity, R-value and U-value
 - 6.5.3 Selection criteria for climate and building type

- 6.5.4 Retrofitting insulation for existing buildings
- 6.6 Solar passive architecture
 - 6.6.1 Principles of passive solar design
 - 6.6.2 Orientation, shading and day-lighting
 - 6.6.3 Natural ventilation techniques
 - 6.6.4 Thermal mass utilization
 - 6.6.5 Integration with energy-efficient building design

7 Energy Audit Cost and Case Studies (4 hours)

- 7.1 Energy audit cost estimation for basic audit, detailed audit (General audit) and investment grade audit
- 7.2 Case studies of energy audits: Overview of industrial and building energy audit, analysis of typical an energy audit reports

Tutorial (30 hours)

- 1. Case studies on successful energy efficiency programs globally and in Nepal
- 2. Compare energy star ratings for appliances and calculate lifecycle cost savings
- 3. Analyze utility bills (Electricity, fuel) to calculate energy costs, consumption trends and load profiles
- 4. Calculate specific energy consumption for a given industry (kWh/ton of cement) and benchmark against national/international standard
- 5. Given operational data for a process (Boiler, furnace), construct a mass balance and an energy balance.
- 6. Develop a Sankey diagram to visualize energy inputs, useful output, losses and identify major loss areas
- 7. Draw Sankey diagram of a country, institution and a home showing energy flow from inputs to end uses and identify the largest loss and conservation opportunity in each

Practical (15 hours)

- 1. Laboratory class on operation of energy audit instruments: Power quality analyzer, clamp meter, multimeter, lux meter, thermal imager, anemometer, tachometer, pressure gauge and flue gas analyzer with hands-on measurement
- 2. Laboratory class on lighting device efficiency: Measurement of lux levels and power consumption of incandescent, CFL and LED lamps with calculation of efficacy and retrofitting potential
- 3. Laboratory class on cooking device efficiency: Controlled testing of induction stove, LPG stove, electric hot plate and improved cookstove by heating water to calculate efficiency and cost comparison
- 4. Laboratory class on building envelope analysis: Using thermal image camera to identify insulation defects, air leaks, thermal bridges and overheating in walls, windows and electrical panels

- Laboratory class on mock walk-through audit: Equipment inventory, utility bill analysis, lighting and HVAC assessment, identification of energy conservation opportunities and preparation of brief audit report

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	Mark distribution*
1 and 7	8	8
2	6	8
3	6	8
4	13	20
5	6	8
6	6	8
Total	45	60

* There may be minor deviation in marks distribution.

References

- Gottschalk, C. M. (1996). Industrial energy conservation (Latest Edition). John Wiley & Sons.
- Krarti, M. (2011). Energy audit of building systems: An engineering approach. CRC Press, Taylor & Francis Group.
- O'Callaghan, P. (1993). Energy management (Latest Edition). McGraw-Hill Education.
- Thumann, A., Niehus, T., Younger, W. J. (2012). Handbook of energy audits. Fairmont Press.
- Turner, W. C. (2001). Energy management handbook. Fairmont Press.

HEATING, VENTILATION AND AIR CONDITIONING SYSTEM

ENME 367

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to provide comprehensive knowledge of the properties of air and the psychrometric processes that take place in various Heating, Ventilating and Air Conditioning. After the completion of this course, student will be able to understand the basic issues involved with human comfort with respect to thermal surroundings and analyze the basic structure and operation of major components used in HVAC systems.

- 1 HVAC Systems and Psychrometric Process Review (6 hours)**
 - 1.1 Purpose, components and scope of HVAC systems
 - 1.2 Human thermal comfort parameters (Fanger's PMV and PPD models)
 - 1.3 Indoor air quality fundamentals
 - 1.4 Review of psychrometric properties of air
 - 1.5 Sensible heat and latent heat concepts
 - 1.6 Basic air-conditioning processes (Heating, cooling, humidification, dehumidification)

- 2 Heating and Cooling Load Estimation (12 hours)**
 - 2.1 Heat transfer through building envelope: U-value and R-value calculation
 - 2.2 Conduction through walls, roofs and floors
 - 2.3 Solar heat gain through fenestration (Windows and glazing)
 - 2.4 Internal heat gains (Occupants, lighting, equipment)
 - 2.5 Infiltration and ventilation load calculations
 - 2.6 Sensible heat factor (SHF) and peak load estimation

- 3 HVAC System Types and Selection (7 hours)**
 - 3.1 All-air systems: Constant volume and multizone systems
 - 3.2 All-water systems: Fan coil units and valance systems
 - 3.3 Air-water systems: Induction and chilled beam systems
 - 3.4 Variable air volume (VAV) systems: Operation and control
 - 3.5 Variable refrigerant flow (VRF) systems: Heat pump and heat recovery

- 4 Air Distribution System Design (10 hours)**
 - 4.1 Determination of airflow requirements and required cubic feet per minute (CFM) flow of rooms

- 4.2 Duct design principles: Aspect ratio and velocity constraints
- 4.3 Duct sizing methods: Equal friction, static regain and velocity reduction
- 4.4 Pressure losses in ducts and fittings
- 4.5 Fans and blowers: Performance curves and selection
- 4.6 Air diffusers and terminal devices

5 HVAC Equipment and System Components (8 hours)

- 5.1 Chillers and refrigeration equipment for HVAC
- 5.2 Boilers and heating systems
- 5.3 Cooling towers: Types, selection and water treatment
- 5.4 Air handling units (AHU)
- 5.5 Pumps and piping system design for chilled water
- 5.6 Basic HVAC control strategies
- 5.7 Building management systems (BMS) and HVAC control strategies
- 5.8 Overview of ASHRAE standards

6 Sustainable HVAC and Building Automation (2 hours)

- 6.1 Green building frameworks and energy efficiency
- 6.2 Building automation systems (BAS) and controls

Tutorial (30 hours)

- 1. Psychrometric property determination using charts and software
- 2. Calculation of U-values for composite building walls and roofs
- 3. Estimation of cooling load for a commercial office space
- 4. Solar heat gain calculation including shading and orientation factors
- 5. Comparative selection of HVAC systems for hospitals, malls and residential buildings
- 6. Calculation of duct sizes using the equal friction and static regain methods
- 7. Comparison of an appropriate HVAC system for: Hospital, shopping mall, office building and residential building
- 8. Design a duct system using equal friction method and using static regain method

Practical (15 hours)

- 1. Use of temperature measuring equipment and sling psychrometer
- 2. Anemometer applications: Measuring airflow and friction loss in various duct shapes
- 3. Performance analysis of a window or split air conditioning unit
- 4. Measurement of heat transfer through building envelope materials
- 5. Site visits to observe HVAC installation (AHUs, chillers and ducting)
- 6. Case study report on the HVAC system of a local commercial 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	Mark distribution*
1	6	8
2	12	16
3	8	10
4	10	14
5	7	10
6	2	2
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Althouse, A. D., Turnquist, C. H., Bracciano, A. F. (2023). Modern refrigeration and air conditioning. Goodheart-Willcox.
2. Arora, C. P. (2017). Refrigeration and air conditioning. McGraw-Hill Education.
3. Arora, S. C., Domkundwar, S. (2018). A course in refrigeration and air conditioning. Dhanpat Rai & Co.
4. American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2021). ASHRAE handbook: Fundamentals. ASHRAE.
5. Carrier Air Conditioning Company. (1965). Handbook of air conditioning system design (Latest Edition). McGraw-Hill Education.
6. Rajput, R. K. (2017). A textbook of refrigeration and air conditioning. Katson Books.

MECHATRONICS

ENME 368

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to develop a fundamental understanding of instrumentation and control principles used in mechatronic systems, including sensors, actuators, signal conditioning, and measurement techniques. Emphasis is placed on microcontroller programming and the interfacing of sensors and actuators, enabling the analysis, design, and implementation of basic integrated mechatronic systems for practical engineering applications.

1 Introduction (5 hours)

- 1.1 Mechatronics: Definition and application
- 1.2 Historical perspective
- 1.3 Elements of mechatronic system
- 1.4 Design process
- 1.5 Measurement systems

2 System Modelling (8 hours)

- 2.1 System and its classification
- 2.2 Modeling of systems: Mechanical, fluid, electrical and thermal
- 2.3 Modeling chamber filled with fluid
- 2.4 Modeling pneumatic actuator
- 2.5 Modeling an electric motor

3 Sensors and Signal Conditioning (6 hours)

- 3.1 Sensors: Classification and performance terminology
- 3.2 Static and dynamic characteristics
- 3.3 Smart sensors
- 3.4 Micro and nano sensors
- 3.5 Operational amplifiers
- 3.6 Filters: High-pass, low-pass, band-pass, band-stop
- 3.7 Wheatstone bridge circuit
- 3.8 Pulse width modulation

- 4 Actuators (6 hours)**
- 4.1 Actuators: Definition and classification
 - 4.2 Electrical actuators: Solenoids, relays, DC motors, BLDC motors, stepper motors, servo motors
 - 4.3 Hydraulic and pneumatic actuators
 - 4.4 Piezoelectric actuators
 - 4.5 Smart memory alloy (SMA) actuators
 - 4.6 Magnetorheological (MR) and electrorheological (ER) actuators
- 5 Computing Elements (12 hours)**
- 5.1 Analog to digital converter
 - 5.2 Digital to analog converter
 - 5.3 Microprocessor
 - 5.3.1 Architecture and pin configuration
 - 5.3.2 Arithmetic and logic unit, registers, control unit
 - 5.3.3 Intel 8085A microprocessor
 - 5.3.4 Interfacing
 - 5.3.5 Basics of microprocessor programming
 - 5.4 Microcontroller
 - 5.4.1 Architecture
 - 5.4.2 Input/output interfacing
 - 5.4.3 Sensor and actuator interfacing
 - 5.4.4 Arduino
 - 5.5 Programmable logic control
 - 5.5.1 Need and advantage of PLC
 - 5.5.2 Basic components: CPU, power supply, memory
 - 5.5.3 Ladder diagram
 - 5.5.4 Basic logic operations
 - 5.5.5 Timers and counters
- 6 Feedback and Intelligent Control (8 hours)**
- 6.1 Open loop control system
 - 6.2 Closed loop control system
 - 6.3 Proportional control, PI, PD, PID control
 - 6.4 Pulse width modulation for electric motor control
 - 6.5 Artificial neural network
 - 6.5.1 Basic structure: Input, hidden and output layer
 - 6.5.2 Neuron model and architecture
 - 6.5.3 Learning concept
 - 6.5.4 Feedforward network
 - 6.6 Fuzzy logic control
 - 6.6.1 Fuzzy logic fundamental
 - 6.6.2 Fuzzy sets

6.6.3 Membership functions

6.6.4 Rule-based control

Tutorial

(30 hours)

1. Implementation of design approach in mechatronic systems
2. Modeling of physical and mechatronic systems
3. Analysis and application of sensors and signal conditioning circuits
4. Selection and performance analysis of actuators in mechatronic systems
5. Interfacing and programming of computing elements in mechatronics
6. Analysis of feedback and intelligent control systems

Practical

(15 hours)

1. Modeling and simulation of mechatronic system (First order)
2. Modeling of hydraulic, pneumatic and electric circuit
3. Microcontroller-based sensor interfacing and data acquisition
4. Actuator control using microcontroller (Motor/relay Control)
5. Modeling fuzzy logic and neural networks using MATLAB

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	Mark distribution*
1	5	6
2	8	12
3	6	8
4	6	8
5	12	16
6	8	10
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Bolton, W. (2018). Mechatronics: Electronic control systems in mechanical and electrical engineering. Pearson.
2. Bishop, R. H. (2017). Mechatronics: An introduction. CRC Press.
3. Alciatore, D. G., Hstand, M. B. (2007). Introduction to mechatronics and measurement systems. McGraw-Hill Education.
4. Onwubolu, G. (2005). Mechatronics: Principles and applications. Elsevier.
5. Mahalik, N. P. (2007). Mechatronics: Principles, concepts and applications. Tata McGraw-Hill Education.

ELECTRIC AND HYBRID VEHICLE

ENME 369

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

This course provides fundamental knowledge of electric and hybrid vehicles (EVs and HEVs), covering their history, architecture, design, operation and control strategies. It also addresses energy storage systems, charging infrastructure and the evaluation of their environmental, economic and performance aspects.

- 1 Introduction to Electric and Hybrid Vehicles (4 hours)**
 - 1.1 History and evolution of EVs and HEVs
 - 1.2 Need for electric vehicles: Environmental and energy aspects
 - 1.3 Types of electric vehicles (EVs, HEVs, PHEVs, FCEVs)
 - 1.4 Comparative study: IC engine vehicles versus electric vehicles
 - 1.5 Recent trends in EVs, HEVs and cybersecurity in EVs
 - 1.6 Scenario of Nepal in the context of EVs, HEVs, EV conversion
 - 1.7 Vehicle dynamics, tractive force, power and torque equations, gradeability and acceleration

- 2 Hybrid Vehicle Systems (5 hours)**
 - 2.1 Classification of hybrids: Series, parallel, series-parallel, degree of hybridization
 - 2.2 Architecture and power flow control
 - 2.3 Energy management strategies
 - 2.4 Role of IC engines in hybrids
 - 2.5 Advantages and challenges in HEV design

- 3 Electric Propulsion Systems (8 hours)**
 - 3.1 Electric motor types and characteristics: DC motors (Brushed and brushless), induction motors, permanent magnet motors (PMSM, BLDC)
 - 3.2 Comparisons of efficiency, cost and applications of each motor type
 - 3.3 Motor control techniques: PWM, V/f, FOC
 - 3.4 Regenerative braking system

- 4 Battery Storage Systems (8 hours)**
 - 4.1 Basic components of battery cells

- 4.2 Battery types and their life cycle analysis: Lead acid, NiMH, Li-ion, LFP, solid-state
- 4.3 Battery specifications and performance parameters
- 4.4 Battery management system (BMS) and safety
- 4.5 Battery charging methods: Onboard/off-board chargers
- 4.6 Supercapacitors and flywheel
- 4.7 Thermal management system
- 4.8 Range estimation and energy consumption
- 4.9 Battery recycling and reuse strategies

5 Charging Infrastructure and Power Electronics (8 hours)

- 5.1 Working principle and components of AC and DC charging stations
- 5.2 Types of charging stations: Level 1, 2, DC fast charging
- 5.3 Types of charging connectors and standards: CCS, CHAdeMO, GB/T, Type 2
- 5.4 Standalone charging and solar power charging station
- 5.5 Sizing of charging station
- 5.6 Smart grid and EV charging, wireless charging, G2V, V2G
- 5.7 Social, environment and economic benefits of different charging

6 Safety and Hazard Management (4 hours)

- 6.1 General safety precautions
- 6.2 High-voltage safety precautions
- 6.3 De-energizing high voltage
- 6.4 Safety tools, equipment and safety work process
- 6.5 Fire and thermal runaway protocols

7 Trends, Challenges and Future Technologies (8 hours)

- 7.1 Autonomous EVs and AI integration
- 7.2 Hydrogen fuel cell vehicles
- 7.3 Government policies, incentives and global EVs adoption
- 7.4 Standards and codes followed in EVs
- 7.5 Recycling and sustainability of EVs components
- 7.6 Future trends in mobility and smart transportation

Tutorial (30 hours)

- 1. Comparative analysis of energy consumption and fuel efficiency between EVs and conventional vehicles
- 2. Calculations of vehicle tractive force, power and torque requirement for varying conditions of gradeability and acceleration; Range estimation problems in EVs
- 3. Motor sizing calculations for given EV specifications, estimation of motor output power and efficiency

4. Battery capacity estimation for given drive cycles; Depth of discharge, cycle life and charging time calculations
5. Basic design of small solar-powered charging stations for EVs
6. Design and sizing of AC/DC chargers for different charging mode
7. Payback period, life cycle cost and CO₂ emission savings of EVs compared to ICE vehicles

Practical

(15 hours)

1. Simulation work (MATLAB/Simulink, ANSYS, or any open-source tools) for EV powertrain/components/charging station design
2. Motor performance testing
3. Battery performance testing and BMS observation
4. EV components and their identifications, visit to near EV manufacturing or service center
5. Demonstration of basic EV conversion

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	Mark distribution*
1	4	6
2	5	10
3	8	8
4	8	12
5	8	8
6	4	6
7	8	10
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Ehsani, M., Gao, Y., Longo, S., Ebrahimi, K. (2018). Modern electric, hybrid electric, and fuel cell vehicles: Fundamental theory and design. CRC Press.
2. Denton, T. (2016). Electric and hybrid vehicles. Routledge.
3. Husain, I. (2021). Electric and hybrid vehicles: Design fundamentals. CRC Press.
4. Larminie, J., Lowry, J. (2012). Electric vehicle technology explained. Wiley.

PRODUCTION PLANNING AND CONTROL

ENME 370

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to develop advanced competency in Production Planning and Control (PPC) through the application of analytical models, optimization techniques, and modern digital tools. The course emphasizes systematic decision-making in complex manufacturing environments, focusing on efficient resource utilization, system integration, and real-time production monitoring and control.

1 Production Systems and PPC Framework (4 hours)

- 1.1 Strategic role of PPC in competitive manufacturing
- 1.2 Integration of PPC with supply chain and enterprise systems
- 1.3 Push and pull systems: Analytical comparison
- 1.4 Hierarchical production planning framework
- 1.5 PPC in flexible, agile and reconfigurable manufacturing systems
- 1.6 Case-based analysis of modern production systems

2 Advanced Forecasting and Demand Planning (5 hours)

- 2.1 Time-series decomposition (Additive and multiplicative models)
- 2.2 Advanced forecasting models: ARIMA (Conceptual), exponential smoothing variants
- 2.3 Causal forecasting and multivariate regression models
- 2.4 Forecast error analysis (MAD, MSE, MAPE) and bias tracking
- 2.5 Demand uncertainty and risk pooling
- 2.6 Collaborative forecasting and demand planning in supply chains

3 Aggregate Planning and Capacity Optimization (6 hours)

- 3.1 Mathematical models for aggregate planning
- 3.2 Linear programming formulation of aggregate plans
- 3.3 Transportation model applications
- 3.4 Capacity planning under constraints
- 3.5 Workforce planning with hiring/layoff costs
- 3.6 Multi-objective optimization (Cost versus service level)
- 3.7 Use of software tools for solving planning problems

- 4 Advanced Material Requirement Planning (MRP) (6 hours)**
- 4.1 Material planning schedule stability, time fences and rolling schedules
 - 4.2 Advanced MRP logic (Lot sizing rules: EOQ, LFL, POQ, Wagner-Whitin model)
 - 4.3 Capacity requirements planning (CRP) with finite loading
 - 4.4 Closed-loop MRP and manufacturing resource planning (MRP II)
 - 4.5 ERP systems architecture and modules (SAP/Oracle overview)
 - 4.6 Data integrity and system integration issues
- 5 Inventory Optimization Models (5 hours)**
- 5.1 Deterministic and probabilistic inventory models
 - 5.2 Multi-item inventory control and constraints
 - 5.3 Stochastic inventory models (Service level approach)
 - 5.4 Periodic review systems (P, Q systems)
 - 5.5 Multi-echelon inventory systems (basic concepts)
 - 5.6 Inventory optimization using simulation tools
- 6 Advanced Scheduling and Sequencing (6 hours)**
- 6.1 Scheduling in complex systems (Flow shop, job shop, open shop)
 - 6.2 Optimization objectives: Makespan, tardiness, flow time
 - 6.3 Heuristic and metaheuristic approaches (Genetic algorithm concept, priority rules)
 - 6.4 Johnson's rule and extensions
 - 6.5 Finite versus infinite loading
 - 6.6 Real-time scheduling and dynamic rescheduling
 - 6.7 Applications in CNC and automated systems
- 7 Shop Floor Control and Real-Time PPC (4 hours)**
- 7.1 Advanced dispatching and control strategies
 - 7.2 Work-in-process (WIP) control and throughput analysis
 - 7.3 Bottleneck analysis (Theory of constraints)
 - 7.4 Drum-buffer-rope system
 - 7.5 Real-time data acquisition (IoT in production systems)
 - 7.6 Manufacturing execution systems (MES)
- 8 Lean, JIT and Agile Production Systems (5 hours)**
- 8.1 Lean system design and value stream mapping (VSM)
 - 8.2 Advanced Kanban systems and pull control
 - 8.3 Just-in-Time in high variability environments
 - 8.4 Agile manufacturing and mass customization
 - 8.5 Hybrid systems (Lean and MRP integration)
 - 8.6 Case studies (Automotive, electronics industries)

9 Integration of Maintenance, Quality and PPC

(4 hours)

- 9.1 Maintenance planning in PPC (TPM integration)
- 9.2 Quality planning and control in production scheduling
- 9.3 Impact of reliability on production plans
- 9.4 Performance metrics: OEE, cycle time, throughput
- 9.5 Smart factories and cyber-physical systems
- 9.6 Digital twins in production planning
- 9.7 AI and machine learning in PPC
- 9.8 Big data analytics for production optimization
- 9.9 Future trends in production management

Tutorial

(30 hours)

1. Numerical problems on:
 - a. Aggregate planning using linear programming
 - b. MRP and lot-sizing techniques
 - c. Inventory models (Probabilistic and multi-item)
 - d. Scheduling optimization problems
2. Case studies on ERP, Lean and TOC
3. Software-based exercises (Excel solver, basic simulation)
4. Group discussions and presentations on industrial applications

Practical

(15 hours)

1. Forecasting and demand analysis using spreadsheets/software
2. Aggregate planning using optimization tools
3. MRP simulation and ERP-based exercises (Demo-based)
4. Scheduling using Gantt charts and software tools
5. Simulation of production systems (Basic discrete-event models)
6. Mini-project: Design and analysis of PPC system for a manufacturing case

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	Mark distribution*
1 and 7	8	11
2	5	7
3	6	8
4	6	8
5	5	7
6	6	8
8	5	7
9	4	4
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Vollmann, T. E., Berry, W. L., Whybark, D. C., Jacobs, F. R. (2017). Manufacturing planning and control for supply chain management. McGraw-Hill.
2. Silver, E. A., Pyke, D. F., Thomas, D. J. (2016). Inventory and production management in supply chains. CRC Press.
3. Nahmias, S., Olsen, T. L. (2015). Production and operations analysis. Waveland Press.
4. Stevenson, W. J. (2021). Operations management. McGraw-Hill.
5. Heizer, J., Render, B., Munson, C. (2020). Operations management. Pearson.
6. Krajewski, L. J., Malhotra, M. K., Ritzman, L. P. (2019). Operations management: Processes and supply chains. Pearson.
7. Pinedo, M. (2016). Scheduling: Theory, algorithms and systems. Springer.
8. Slack, N., Brandon-Jones, A., Johnston, R. (2019). Operations management. Pearson.