AI FOR ELECTRICAL ENGINEERING
ENEE 425

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

Course Objectives:
The objective of this course is to introduce Artificial Intelligence (AI) and Machine Learning (ML) techniques with applications in electrical engineering. Students will learn data-driven modelling, prediction, optimization, classification, and intelligent decision-making techniques for modern electrical systems.

1 Introduction to AI in Electrical Engineering (4 hours)

1.1 Introduction to Artificial Intelligence
1.2 1.2 Evolution of AI, Machine Learning and Deep Learning
1.3 1.3 AI workflow and problem formulation
1.4 1.4 Comparison of data-driven modelling and physics-based modelling
1.5 1.5 Overview of AI applications in electrical engineering

2 Data Analytics and Machine Learning Fundamentals (14 hours)

2.1 Data sources in electrical engineering: SCADA systems
  2.1.1 Smart meters
  2.1.2 Phasor Measurement Units (PMUs)
  2.1.3 IoT sensors
  2.1.4 Asset monitoring systems
2.2 Data preprocessing
  2.2.1 Missing values and data cleaning
  2.2.2 Outlier treatment
  2.2.3 Feature engineering and selection
  2.2.4 Data normalization and standardization
2.3 Basic exploratory data analysis and visualization
2.4 Fundamentals of machine learning
  2.4.1 Supervised and unsupervised learning
  2.4.2 Regression and classification problems
2.5 Representative machine learning algorithms
  2.5.1 Linear and Logistic Regression
  2.5.2 Decision Trees and Random Forest
  2.5.3 K-Means clustering
  2.5.4 Artificial Neural Networks (ANN)
2.6 Basic model evaluation
  2.6.1 Training, validation and testing datasets

2.6.2 Basic performance measures
2.6.3 Over fitting and under fitting

3 Introduction to Deep Learning (8 hours)

3.1 Deep Neural Networks (DNN)
3.1.1 Concept of depth and hidden layers
3.1.2 Basic idea of DNN architecture
3.1.3 Overview of DNN applications
3.2 Recurrent Neural Networks and LSTM
3.2.1 Sequential data and temporal dependence
3.2.2 Basic concept of Recurrent Neural Networks (RNN)
3.2.3 Introduction to Long Short-Term Memory (LSTM) networks
3.2.4 LSTM for time series forecasting

4 Meta-Heuristics Based Optimization (8 hours)

4.1 Optimization problem formulation, Objective functions and constraints
4.2 Conventional and meta-heuristic optimization methods
4.3 Need for meta-heuristic algorithms
4.4 Genetic Algorithms (GA) and Particle Swarm Optimization (PSO)
4.5 Introduction to Multi-objective Optimization: Pareto optimality and trade-off analysis

5 AI Applications in Power and Energy Systems (11 hours)

5.1 AI for Forecasting
5.1.1 Load forecasting
5.1.2 Solar and wind power forecasting
5.1.3 Selection of suitable AI/ML methods for forecasting
5.2 AI for Fault Detection and Classification
5.2.1 Fault detection and classification in power systems
5.2.2 Data-driven fault diagnosis
5.3 AI for Condition Monitoring
5.3.1 Transformer condition monitoring and diagnostics
5.3.2 Electrical machine condition monitoring
5.3.3 Intelligent asset monitoring
5.4 AI for Smart Grid Applications
5.4.1 Demand response
5.4.2 Energy management
5.4.3 Distribution system monitoring and state estimation
5.5 AI-based Optimization Applications
5.5.1 Economic dispatch
5.5.2 Unit commitment
5.5.3 Volt/VAR control
5.5.4 Microgrid energy management

5.6 5.6 Emerging Applications of AI in Electrical Engineering
- 5.6.1 Electric vehicles and charging systems
- 5.6.2 Digital twins and intelligent monitoring systems
- 5.6.3 Selected case studies in power and energy systems

Tutorial **(30 hours)**

1. AI/ML workflow and formulation of electrical engineering problems
2. 2. Electrical engineering datasets: data types, data quality, data acquisition and basic data analysis
3. 3. Data preprocessing: missing values, data cleaning, outlier treatment, normalization and standardization
4. 4. Feature selection, feature engineering and data visualization
5. 5. Regression problems using electrical engineering datasets
6. 6. Classification problems using electrical engineering datasets
7. 7. Decision Tree, Random Forest and K-Means exercises
8. 8. ANN concepts and basic modelling exercises
9. 9. Model evaluation: training, validation and testing, performance measures, overfitting and underfitting
10. 10. Introduction to DNN, RNN and LSTM: conceptual and comparative exercises
11. 11. Sequential data and time-series forecasting exercises
12. 12. Optimization problem formulation, objective functions and constraints
13. 13. Genetic Algorithm: basic procedure and numerical exercises
14. 14. Particle Swarm Optimization and multi-objective optimization exercises
15. 15. Application-oriented case studies in electrical engineering: forecasting, fault diagnosis, condition monitoring, smart grids and power-system optimization

Practical **(15 hours)**

1. Python fundamentals and introduction to AI/ML libraries for electrical engineering applications
2. Data preprocessing and visualization using smart meter, SCADA or other electrical engineering datasets
3. Regression and classification using electrical engineering datasets
4. Comparison and evaluation of machine learning models using basic performance measures
5. Artificial Neural Network and basic deep-learning modelling using electrical engineering data
6. Time-series forecasting using LSTM and renewable energy or load data
7. AI-based optimization using Genetic Algorithm and Particle Swarm Optimization, with a simple electrical engineering application
8. Mini-project using a real or representative electrical engineering dataset

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	5
2	14	20
3	8	11
4	8	12
5	11	12
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Borlase, S. (2018). Smart Grids: Advanced Technologies and Solutions. CRC Press.
2. Zobaa, A. F., & Bihl, T. J. (2018). Big Data Analytics in Future Power Systems. CRC Press.
3. Géron, A. (2022). Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. O'Reilly Media.
4. Müller, A. C., & Guido, S. (2016). Introduction to Machine Learning with Python: A Guide for Data Scientists. O'Reilly Media.
5. Yang, X. S. (2010). Engineering Optimization: An Introduction with Metaheuristic Applications. John Wiley & Sons.

ELECTRIC TRACTION AND TRANSPORTATION SYSTEMS
ENEE 426

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

Course Objectives:
To introduce the principles, systems, and applications of electric traction; to develop the ability to solve basic problems in traction mechanics, power supply, and traction drives; and to build an understanding of traction motors, current collection systems, and modern electric transportation systems.

1 Introduction to Electric Traction (4 hours)

1.1 Development and importance of electric traction
1.2 Advantages and limitations of electric traction
1.3 Requirements of an ideal traction system
1.4 Basic components of an electric traction system,
1.5 Overview of electric transportation in Nepal

2 Types of Traction and Traction Mechanics (8 hours)

2.1 Types of Traction Systems: Non-electric traction: steam and diesel, externally supplied/grid-fed electric traction, Self-contained traction system, Diesel-electric traction, Hybrid traction system, Battery-operated traction: battery electric bus, battery electric train and battery electric tram
2.2 Electric Transportation Systems: Trolleybus, Tram, Light Rail Transit (LRT), Metro, Monorail, Conventional electric train, High-speed/fast train, Maglev, Cable car/ropeway.
2.3 Traction Mechanics: Types of railway services, Speed-time curves: trapezoidal and quadrilateral, Average, schedule and maximum/crest speed, Tractive effort, Train resistance, Gradient and curve resistance, Adhesion and coefficient of adhesion, Power and energy requirements, Specific energy consumption, Effect of coasting and regenerative braking

3 Electric Traction Power Supply System and Traction Substation (7 hours)

3.1 DC traction systems: 600/750 V, 1500 V and 3000 V
3.2 AC traction systems: single-phase 25 kV, 50 Hz and 2 × 25 kV autotransformer system
3.3 Comparison of AC and DC traction systems
3.4 Selection of traction supply system

3.5 Basic traction substation arrangement
3.6 Traction transformer and rectifier for DC traction
3.7 Circuit breakers, isolators, and feeding/sectioning arrangements
3.8 Basic idea of substation spacing, rating, and simple voltage-drop concept

4 Current Collection Systems (4 hours)

4.1 Overhead line system and catenary system (simple and compound)
4.2 Contact wire and messenger wire
4.3 Pantograph: construction and working
4.4 Third-rail system
4.5 Trolleybus twin overhead wires
4.6 Current collector/shoe/bow
4.7 Comparison of current collection methods

5 Traction Motors and Control (8 hours)

5.1 Traction Motors: Requirements of a traction motor, Characteristics of traction motors, DC series motor, Three-phase induction motor, Permanent magnet synchronous motor (PMSM), BLDC motor – basic concept and application, Comparison and selection of traction motors
5.2 Traction Motor Control: Starting and speed control of traction motors; resistance control, series-parallel control, chopper control, and basic converter and inverter control
5.3 Electric Traction Drive Systems: Basic arrangement and operation of electric traction drives; rectifier, DC link, inverter, and traction motor; multiple-motor drive systems; battery-electric traction drive systems
5.4 Traction Performance and Braking: Speed–tractive effort characteristics, Torque–speed characteristics, Acceleration and retardation, Energy-efficient driving

6 Transportation Systems and Applications (14 hours)

6.1 Trolleybus: Basic electrical arrangement, 600/750 V DC supply, Twin overhead wires, Current collection, Traction motor and control, Battery-assisted/dual-mode operation
6.2 Tram and LRT: Basic arrangement, Power supply, Traction drive, Braking, Difference between tram and LRT, Basic catenary-free operation.
6.3 Metro Railway: Underground and elevated metro, 750 V DC third rail, DC overhead supply, Basic 25 kV AC application, Regenerative braking, Station auxiliary supply
6.4 Conventional and High-Speed Electric Train: Electric locomotive, Electric Multiple Unit (EMU), Mainline railway, electrification, 25 kV AC system, 2 × 25 kV system, High-speed train, Pantograph and catenary requirements, Basic power and energy considerations

6.5 Monorail: Straddle and suspended types, Guideway, Power supply, Traction and braking

6.6 Battery Electric Transportation: Battery electric bus, Battery electric train, Battery electric tram, Battery types: Li-ion and LFP, Battery Management System (BMS), Charging methods, Regenerative braking, Basic battery sizing concept

6.7 Cable Car : Gondola, Aerial tramway, Funicular, Basic electric drive, Motor control, Braking and emergency drive, Backup power supply, Basic safety requirements

Tutorial **(30 hours)**

1. Basic electric traction system block diagram, comparison of traction systems, and case study of electric transportation development in Nepal.
2. Numerical problems on speed–time curves, average and schedule speed, tractive effort, train resistance, gradient and curve resistance, adhesion, power and energy requirements, specific energy consumption, coasting and regenerative braking; mainly focused on numerical problem solving.
3. Numerical and design exercises on comparison of DC and AC traction supply systems, traction transformer and rectifier rating, feeder current, voltage-drop calculations, substation spacing, basic traction substation single-line diagram, and feeding and sectioning arrangements.
4. Design, diagram and comparison of simple and compound catenary, OHE arrangement, contact and messenger wires, pantograph, third-rail and trolleybus twin-wire systems, current collectors and electrical clearances, with simple numerical calculations where required.
5. Numerical and traction-drive exercises on DC and induction motor characteristics, PMSM and BLDC applications, torque–speed and speed–tractive-effort characteristics, motor rating and selection, starting and speed control, chopper and inverter control, basic traction-drive arrangement, acceleration and retardation, and regenerative braking.
6. Case Studies, Group Presentations and Application-Oriented Design: Trolleybus, tram/LRT, metro, conventional and high-speed railway, monorail, battery-electric transportation and cable-car systems; basic battery sizing, charging requirements, regenerative braking, comparison of transportation systems, and case studies of electric transportation in Nepal

Practical **(15 hours)**

1. Study of Electric Traction System: Identification and study of major components of a railway traction system, including traction motor, converter, transformer, current collection system and associated equipment.
2. Study of a traction substation, transformer, feeder, overhead line/current collection and return-current system.
3. Mini Project: Small group project involving analysis, simulation, design or energy study of an electric traction system, followed by presentation and report

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	8	10
3	7	10
4	4	6
5	8	10
6	14	18
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Morris Brenna, Federica Foiadelli, Dario Zaninelli (2018). “Electrical Railway Transportation Systems” John Wiley & sons.
2. Andreas Steimel "Electric Traction Motive Power and Energy Supply” (2008) , Oldenbourg Industrieverlag Munchen
3. H. Partab (2018) “Modern Electric Traction” Dhanpat Rai & Sons.
4. Tarlok Singh, (2018) “Modern Electric Traction”, SK Kataria
5. M.A.Chaudhari, S.M. Chaudhari (2018) “Modern Electric Traction”, Nirali Prakashan

RELIABILITY ENGINEERING
ENEE 427

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

Course Objectives:
The objective of this course is to impart students the fundamental understanding of reliability engineering concepts and system analysis techniques, with major focus on reliability modeling, probability distributions, Markov processes, frequency and duration techniques, and reliability evaluation of electrical power systems.

1 Basic Reliability Concepts (4 hours)

1.1 Structure Review of probability concepts
1.2 Venn diagram
1.3 Practical engineering application rules for combining probability
1.4 Concept of reliability of an engineering system and its optimal level
1.5 Incremental reliability

2 Probability distributions (6 hours)

2.1 Concept of transition rates and failure rates
2.2 Failure distribution function and failure density function
2.3 Reliability function
2.4 Exponential distribution and its applications
2.5 Poisson distribution and their applications
2.6 Binomial distribution and its applications
2.7 Introduction to Weibull, Gamma, Rayleigh, Lognormal and rectangular distributions

3 Reliability network modeling of engineering systems (10 hours)

3.1 Modeling of simple systems: series and parallel systems
3.2 Redundancy and standby systems, perfect and imperfect switching
3.3 Modeling of complex systems
3.4 Conditional probability approach
3.5 Cut-set and tie-set methods
3.6 Connection matrix
3.7 Event tree
3.8 Fault tree techniques
3.9 Multi-failure modes
3.10 Application in engineering systems

4 Reliability evaluation using probability distribution (4 hours)

4.1 Reliability evaluations to series system
4.2 Reliability evaluation of parallel system
4.3 Concept of equivalent failure rates of series system
4.4 Concept of equivalent forced outage rate of parallel system
4.5 Mean time to failure

5 Markov Processes (8 hours)

5.1 Discrete Markov chains-modeling concepts
5.2 STPM and time dependent probability evaluation
5.3 Limiting state probability evaluation
5.4 State space diagram
5.5 Application of Markov Chains
5.6 Continuous Markov Process-modeling concepts, transition rates
5.7 Limiting state probability
5.8 State space diagram
5.9 Repairable and non-repairable systems
5.10 Single, two and three state systems and their evaluation techniques
5.11 Application of continuous Markov Process to engineering systems

6 Frequency and duration techniques (9 hours)

6.1 Concept of F&D techniques
6.2 MTTF, MTTR, MTBF, Cycle frequency, Cycle time
6.3 Application to single, two and three component systems
6.4 Two stage repair and installation process: single component; one and more spares; limiting number of spares
6.5 Concept of cumulated states and frequency
6.6 Frequency balance approach
6.7 Applications in two, three and four state systems

7 Approximate Reliability Evaluation Techniques (4 hours)

7.1 Concept of equivalent failure rates, repair rates
7.2 Availability and unavailability of series system
7.3 Availability and unavailability of parallel system

Tutorial (30 hours)

1. Reliability evaluation of simple series and parallel systems
2. Reliability analysis of systems with redundancy and standby components
3. Reliability modeling of complex systems using conditional probability
4. Application of cut-set and tie-set methods for system reliability evaluation
5. Reliability analysis using connection matrices, event-tree techniques, Fault-tree analysis and evaluation of systems with multiple failure modes
6. Reliability evaluation using Weibull and other probability distributions

7. Calculation of equivalent failure rates, forced outage rates, and mean time to failure
8. Modeling and analysis of discrete Markov chains for engineering systems
9. Continuous Markov process modeling and limiting-state probability evaluation
10. Reliability evaluation of repairable and non-repairable single-, two-, and three-state systems
11. Application of frequency and duration techniques for availability and reliability assessment

Practical **(15 hours)**

1. Comparative study of reliability assessment methods and performance of different sections of an electrical power system
2. Development of state-space models and application of Markov processes for evaluating the reliability and availability of electrical systems
3. Identification of system failure mechanisms and evaluation of the probability and consequences of major failure events
4. Evaluation of distribution-system reliability using indices such as SAIFI, SAIDI, CAIDI, ASAI, and ENS
5. Study of the impact of renewable energy sources, energy storage, and distributed generation on power-system reliability and resilience

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	6	6
3	10	12
4	4	6
5	8	12
6	9	12
7	4	6
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Billinton, R., & Allan, R. N. (1992). Reliability evaluation of engineering systems: Methods and techniques. Plenum Press.
2. Billinton, R., & Allan, R. N. (1993). Reliability evaluation of power systems. Plenum Press.

3. Li, W. (2005). Risk assessment of power systems: Models, methods, and applications. Wiley-IEEE Press.
4. Billinton, R. (1987). Power system reliability evaluation. [Publisher not provided].
5. Smith, W. H. (2018). Electric power system reliability. Alphagraphics-Roswell GA.
6. Brown, R. E. (2017). Electric power distribution reliability (2nd ed.). Taylor & Francis.