SIDDHARTHA
ACADEMY OF HIGHER EDUCATION
An Institution DEEMED TO BE UNIVERSITY
(Under Section 3 of UGC Act, 1956)
Kanuru, Vijayawada - 520 007, AP. www.vrsiddhartha.ac.in
91 866 2582333
866 2582334
866 2584930

Department of Electrical and Electronics Engineering

POOL I Courses:

S.No	Code	Title of the Course	L	T	P	C	SE	Total
1	24EE710A	Deregulated Power System	3	0	0	3	100	100
2	24EE710B	Smart Grid Design and Analysis	3	0	0	3	100	100
3	24EE710C	Modern Control Theory	3	0	0	3	100	100
4	24EE710D	Analysis and design of power converters	3	0	0	3	100	100
5	24EE710E	Sustainable Power Generation Systems	0	0	0	3	100	100
6	24EE710F	Optimization Theory and Algorithms (NPTEL)	0	0	0	3	100	100
7	24EE710G	Design of Photovoltaic Systems (NPTEL)	0	0	0	3	100	100
8	24EE710H	Power Electronics with Wide Band Gap Devices (NPTEL)	0	0	0	3	100	100
9	24EE710I	Nonlinear Dynamical Systems and Control (NPTEL)	0	0	0	3	100	100
10	24EE710J	Introduction to Electric and Hybrid Electric Vehicle (NPTEL)	0	0	0	3	100	100

POOL II Courses:

S.No	Code	Title of the Course	L	T	P	C	SE	Total
1	24EE720A	Flexible AC Transmission Systems	3	0	0	3	100	100
2	24EE720B	Advanced Power System Protection	3	0	0	3	100	100
3	24EE720C	Battery Technology for Electrical Vehicles	3	0	0	3	100	100
4	24EE720D	Power Electronics applications to renewable energy systems	3	0	0	3	100	100
5	24EE720E	Analysis and design of Inverters	3	0	0	3	100	100
6	24EE720F	Solar Energy Engineering and Technology (NPTEL)	0	0	0	3	100	100
7	24EE720G	Distributed Optimization and Machine Learning (NPTEL)	0	0	0	3	100	100
8	24EE720H	Power Electronics Applications in Power Systems (NPTEL)	0	0	0	3	100	100
9	24EE720I	Hydrogen Energy: Production, Storage, Transportation and Safety (NPTEL)	0	0	0	3	100	100
10	24EE720J	Machine Learning and Deep Learning - Fundamentals and Applications (NPTEL)	0	0	0	3	100	100

L – Lecture, T – Tutorial, P – Practical, SE–Semester End Exam, C – Credits, Total – Total Marks

POOL I — COURSES SYLLABUS

24EE710A - Deregulated Power System

Course Objectives:

- **CO1:** Describe the operation of deregulated electricity market systems.
- **CO2:** Analyze typical issues in electricity markets and how these are handled worldwide in various markets.
- **CO3:** Analyze various types of electricity market operational and control issues using new mathematical models.
- **CO4:** Illustrate reforms in the Indian power sector and Availability Based Tariff (ABT).

UNIT-I:

Introduction, Deregulation of electric utilities, Competitive wholesale electricity market: Transmission expansion in a new environment, Transmission open access, Pricing electricity in a deregulated environment.

UNIT-II:

Fundamentals of Deregulation: Privatization and deregulation, Motivations for restructuring the power industry; Restructuring models and trading arrangements: Components of restructured systems, Independent System Operator (ISO): Functions and responsibilities, Trading arrangements (Pool, bilateral & multilateral).

UNIT-III:

Open Access Transmission Systems: Different models of deregulation: UK Model, California model, Australian and New Zealand models, Deregulation in Asia including India, Bidding strategies,Forward and future markets; Operation and control: Old vs New, Available Transfer Capability, Congestion management, Ancillary services. Wheeling charges and pricing: Wheeling methodologies, Pricing strategies.

UNIT-IV:

Reforms in the Indian power sector, Framework of the Indian power sector, National and Transnational Grids, The Independent Power Plants: Orissa Reform Model, Accelerated Power Development and Reforms Program (APDRP), Public-Private Partnership, The Availability Based Tariff (ABT).

References:

1. Yong-Hua Song, Xi-Fan Wang, *Operation of Market Oriented Power Systems*, Springer, 2003.
2. Daniel Kirschen and Goran Strbac, *Fundamentals of Power System Economics*, John Wiley & Sons Ltd, 2004.
3. Kankar Bhattacharya, Jaap E. Daadler, Math H.J Bollen, *Operation of Restructured Power Systems*, Kluwer Academic Publishers, 2001.

24EE710B - Smart Grid Design and Analysis

Course Objectives:

- **CO1:** Analyze the concepts and design of Smart Grid.
- **CO2:** Apply various communication and measurement technologies in Smart Grid.
- **CO3:** Analyze the stability of Smart Grid.
- **CO4:** Learn the renewable energy resources and storages integrated with Smart Grid.

UNIT-I: Smart grid concepts & architectural designs

Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart Grid drivers, functions, opportunities, challenges, and benefits, Difference between conventional & Smart Grid, Concept of Resilient & Self-Healing Grid, Present development & International policies in Smart Grid, Diverse perspectives from experts and global Smart Grid initiatives. General view of the Smart Grid market drivers - Stakeholder Roles and Functions - Measures - Representative Architecture - Functions of Smart Grid Components - Wholesale energy market in Smart Grid - Smart vehicles in Smart Grid.

UNIT-II: Smart grid communications and measurement technology

Communication and standards - Communication and Measurement - Monitoring, Introduction to Smart Meters, Advanced Metering Infrastructure (AMI)– (GIS and Google Mapping Tools) drivers and benefits, AMI protocols, standards, and initiatives, AMI needs in Smart Grid, Phasor Measurement Unit (PMU), Intelligent Electronic Devices (IED) & their application for monitoring & protection. Wide area monitoring systems (WAMS).

UNIT-III: Performance analysis tools for Smart Grid design

Introduction to Load Flow Studies - Challenges to Load Flow in Smart Grid and Weaknesses of the Present Load Flow Methods - Load Flow State of the Art: Classical, Extended Formulations, and Algorithms – Load flow for Smart Grid design - Contingencies studies for Smart Grid.

Stability analysis tools for Smart Grid: Voltage Stability Analysis Tools - Voltage Stability Assessment Techniques - Voltage Stability Indexing - Application and Implementation Plan of Voltage Stability in Smart Grid - Angle stability assessment in Smart Grid - Approach of Smart Grid to State Estimation - Energy management in Smart Grid.

UNIT-IV: Renewable energy integration, storage & monitoring technologies

Renewable Energy Resources - Sustainable Energy Options for the Smart Grid - Penetration and Variability Issues Associated with Sustainable Energy Technology - Demand Response Issues - Electric Vehicles and Plug-in Hybrid Electric Vehicles - PHEV Technology - Environmental Implications - Storage Technologies - Grid integration issues of renewable energy sources (Power Quality & EMC) - Web-based Power Quality monitoring (LAN, HAN, WAN, Broadband over Power Line, IP-based Protocols), Power Quality Audit, Basics of Web Service and CLOUD Computing to make Smart Grids smarter, Cyber Security for Smart Grid.

References:

1. James Momoh, *Smart Grid: Fundamentals of Design and Analysis*, John Wiley & Sons Inc, IEEE Press, 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, *Smart Grid: Technology and Applications*, John Wiley & Sons Inc, 2012.
3. Fereidoon P. Sioshansi, *Smart Grid: Integrating Renewable, Distributed & Efficient Energy*, Academic Press, 2012.
4. Clark W. Gellings, *The Smart Grid: Enabling Energy Efficiency and Demand Response*, Fairmont Press Inc, 2009.

24EE710C - Modern Control Theory

Course Objectives:

- **CO1:** Design a control system via pole assignment and observer using state feedback.
- **CO2:** Perform the stability analysis of nonlinear systems using describing functions and phase plane methods.
- **CO3:** Analyze linear and non-linear systems using Lyapunov theorems and design Lyapunov function for stable systems.
- **CO4:** Formulate an optimal control problem and design an optimal controller using Hamiltonian and/or LQR methods.

UNIT-I: State feedback controllers and observers

Review of state space concepts, Controllability and Observability, State space representations of transfer-function systems – controllable, observable, diagonal (Jordan) canonical forms; State feedback controller design through Pole Assignment - Direct, Transformation Matrix, Ackermann's methods; State observers - Full order and Reduced order - Direct, Transformation Matrix, Ackermann's methods.

UNIT-II: Nonlinear Systems

Introduction – Properties of nonlinear systems - Types of Nonlinearities – Singular Points – Introduction to linearization of nonlinear systems – Describing function – Describing function analysis of nonlinear systems – Stability analysis of Nonlinear systems - Describing function and phase plane methods.

UNIT-III: Lyapunov Stability Analysis

Equilibrium state, Stability in the sense of Lyapunov, Scalar functions - Sign definiteness, Lyapunov's stability and instability theorems - Stability analysis of the linear continuous-time invariant systems by Lyapunov second method – Direct method of Lyapunov – Generation of Lyapunov functions – Variable gradient and Krasovskii's methods.

UNIT-IV: Optimal Control

Introduction to optimal control - Formulation of optimal control problems – Calculus of variations – Minimization of functions - Minimization of functional – Functional involving independent functions – Constrained minimization – Formulation using Hamiltonian method – Linear Quadratic Regulator (LQR).

References:

1. M. Gopal, *Modern Control System Theory*, New Age International, 3rd Edition.
2. K. Ogata, *Modern Control Engineering*, PHI, 5th Edition.
3. M. Gopal, *Control Systems: Principles and Design*, TMH, 3rd Edition.
4. I. J. Nagrath and M. Gopal, *Control System Engineering*, New Age International, 5th Edition.
5. Manjitha Srivastava et. al., *Control Systems*, TMH.

24EE710D - Analysis and Design of Power Converters

Course Objectives

1. To determine the operation and characteristics of controlled rectifiers
2. To apply switching techniques and basic topologies of DC-DC switching regulators
3. To introduce the design of power converter components
4. To provide an in-depth knowledge about resonant converters

Unit I: Single Phase
Three Phase Converters

Principle of phase-controlled converter operation – single-phase full converter and semi-converter (RL, RLE load) – single-phase dual converter – Three-phase operation full-converter and semi-converter (R, RL, RLE load) – reactive power – power factor improvement techniques – PWM rectifiers.

Unit II: DC-DC Converters

Limitations of linear power supplies, switched mode power conversion, Non-isolated DC-DC converters: operation and analysis of Buck, Boost, Buck-Boost, Cuk SEPIC – under continuous and discontinuous operation – Isolated DC-DC Converters: forward, fly-back, push-pull, half-bridge, and full-bridge converters, relationship between input and output voltages, expression for filter inductor and capacitors.

Unit III: Design of Power Converter Components

Introduction to magnetic materials- hard and soft magnetic materials – types of cores, copper windings – Design of transformer – Inductor design equations – Examples of inductor design for buck/flyback converter – selection of output filter capacitors – selection of ratings for devices – input filter design.

Unit IV: Resonant DC-DC Converters

Switching loss, hard switching, and basic principles of soft switching – classification of resonant converters – load resonant converters – series and parallel – resonant switch converters – operation and analysis of ZVS, ZCS converters – comparison of ZCS/ZVS, Introduction to ZVT/ZCT PWM converters.

Text Books

1. Ned Mohan, T.M. Undeland and W.P. Robbin, “Power Electronics: converters, Application and design”, John Wiley and Sons, Wiley India edition, 2006.

2. Rashid M.H., “Power Electronics Circuits, Devices and Applications”, Prentice Hall India, Third Edition, New Delhi, 2004.

3. P.C. Sen, “Modern Power Electronics”, Wheeler Publishing Co, First Edition, New Delhi, 1998.

4. P.S. Bimbra, “Power Electronics”, Khanna Publishers, Eleventh Edition, 2003.

5. Simon Ang, Alejandro Oliva, “Power-Switching Converters, Second Edition, CRC Press, Taylor
Francis Group, 2010.

6. V. Ramanarayanan, “Course material on Switched mode power conversion”, 2007.

7. Alex Van den Bossche and Vencislav Cekov Valchev, “Inductors and Transformers for Power Electronics”, CRC Press, Taylor
Francis Group, 2005.

8. W.G. Hurley and W.H. Wolfle, “Transformers and Inductors for Power Electronics: Theory, Design and Applications”, John Wiley
Sons Ltd, 2013.

24EE710E - Sustainable Power Generation Systems

About the Course

The course content is designed to provide comprehensive knowledge of various renewable energy systems. Specifically, in this course, the design and analysis of renewable energy power plants will be discussed. The concepts will be illustrated with practical examples, schematics, and block diagrams wherever required. A sufficient number of numerical problems with solutions will be discussed in the course. This course is specifically designed for undergraduate and postgraduate students of Energy Engineering and Technology. Further, the course will be very much useful for students and researchers from varied academic backgrounds for the synthesis of novel energy conversion devices and processes.

Course Layout

Week 1: Module-1: Introduction to power generation
Global and Indian scenario, an overview of current technologies available for power generation, Concept of the renewable energy-based power plant.

Week 2: Module-2: Solar Thermal Power Generation
Fundamentals of Solar thermal energy conversion, solar thermal-based power plant design and analysis (flat plate and concentrator), ORC, RC, and Stirling engine.

Week 3: Module-3: Solar Photovoltaic Power Generation
Fundamentals of Solar photovoltaic energy conversion, Solar PV power plant design, Performance analysis of standalone and grid-connected PV systems.

Week 4: Module-4: Wind Power Generation
Introduction to wind turbines, classification and analysis of different components, Theory, design, and analysis of wind turbines (horizontal axis and vertical axis) and wind farms.

Week 5: Module-5: Hydro Power Generation
Introduction to hydro power plants, overview of micro, mini, and small hydro power plants, hydraulic turbines, selection and design criteria of pumps and turbines, Brief theory, design, and analysis of hydro power plants.

Week 6: Module-6: Biomass Power Generation
Fundamentals of bioenergy production technologies through different routes, design and analysis of biochemical and thermochemical reactors for clean power generation and value-added products, IGCC.

Week 7: Module-7: Hydrogen energy and fuel cells
Importance, various routes of hydrogen generation, basic principles and design of different types of fuel cells and their applications, future prospects, IGFC.

Week 8: Module-8: Geothermal Energy
Fundamentals, classification, theory, design, and analysis of geothermal power plants.

Week 9: Module-9: Ocean Thermal Energy
Fundamentals, classification, theory, design, and analysis of ocean thermal power plants.

Week 10: Module-10: Wave and Tidal Energy
Fundamentals, classification, theory, design, and analysis of wave and tidal power plants.

Week 11: Module-11: Energy Storage
Different modes of energy storage; design and analysis of different technologies for thermal, mechanical, and electro-chemical energy storage systems.

Week 12: Module-12: Energy Economics
Cost analysis, interest, Accounting rate of return, Payback, Discounted cash flow, Net present value, Internal rate of return, Inflation, and life cycle analysis of energy systems.

Books and References

1. J. Twidell, T. Weir, Renewable Energy Resources, Taylor and Francis, 4th Edition, 2021.

2. G. Boyle (Editor), Renewable Energy: Power for a Sustainable Future, Oxford University Press, 3rd Edition, 2012.

3. G.N. Tiwari, Solar Energy, Fundamentals, Design, Modeling and Applications, Narosa, 2002.

4. J.A. Duffie and W.A. Beckman, Solar Engineering of Thermal Processes, John Wiley, 4th Edition, 2013.

5. R. Gasch, J. Twele, Wind Power Plants: Fundamentals, Design, Construction and Operation, Springer, 2nd Edition, 2012.

6. P. Breeze, Hydropower, Elsevier, 1st Edition, 2018.

7. S.C. Bhattacharyya, Energy Economics Concepts, Issues, Markets, and Governance, Springer, 2nd Edition, 2019.

8. S.P. Sukhatme and J.K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill Education Private Limited, 3rd Edition, 2010.

24EE710F - Optimization Theory and Algorithms

About the Course

This course will introduce the student to the basics of unconstrained and constrained optimization that are commonly used in engineering problems. The focus of the course will be on contemporary algorithms in optimization. Sufficient critical grounding will be provided to help the student appreciate the algorithms better. Illustrative programming assignments will also be provided to deepen understanding of the subject matter.

Course Layout

Week 1: Introduction and Background Material - 1: Review of Linear Algebra

Week 2: Background Material - 2: Review of Analysis, Calculus

Week 3: Unconstrained Optimization: Taylor's theorem, 1st and 2nd order conditions on a stationary point, Properties of descent directions

Week 4: Line Search Theory and Analysis: Wolfe conditions, backtracking algorithm, convergence and rate

Week 5: Conjugate Gradient Method - 1: Introduction via the conjugate directions method, geometric interpretations

Week 6: Conjugate Gradient Method - 2: Formulating the conjugate gradient method, expanding subspace theorem, preconditioned conjugate gradient method

Week 7: Nonlinear Optimization Methods: Nonlinear conjugate gradient method, Convergence and rate for Newton methods, Hessian modification

Week 8: Linear and Nonlinear Least Squares Problems: Formulations and techniques for solving least square problems

Week 9: Constrained Optimization - Introduction: First order formulation for constrained optimization, equality and inequality constraints, constraint qualification

Week 10: Constrained Optimization - KKT Conditions: First order necessary conditions (KKT) and a proof sketch of KKT

Week 11: Constrained Optimization - Projected Gradient Descent: Subgradients and projection operators, examples of projected gradient descent

Week 12: Duality in Optimization: Geometric interpretations of duality, and sample problem solving using the Lagrangian dual function formulation

Books and References

1. *Numerical Optimization* by Jorge Nocedal and Stephen J. Wright, Springer, 2006.

2. Instructor-supplied notes for this course are available: https://www.ee.iitm.ac.in/uday/notes/opt/.

24EE710G - Design of Photovoltaic Systems

About the Course

This course is a design-oriented course aimed at photovoltaic system design. The course begins by discussing the PV cell electrical characteristics and interconnections. Estimation of insolation and PV sizing is addressed in some detail. Maximum power point tracking and circuits related to it are discussed. Later, applications related to Peltier refrigeration, water pumping, grid connection, and microgrids are discussed in detail. Lastly, a brief discussion on life cycle costing is also included to provide completeness to the course.

Course Layout

Week 1: The PV Cell

Week 2: Series and Parallel Interconnection

Week 3: Energy from Sun

Week 4: Incident Energy Estimation

Week 5: Sizing PV

Week 6: Maximum Power Point Tracking

Week 7: MPPT Algorithms

Week 8: PV-Battery Interfaces

Week 9: Peltier Cooling

Week 10: PV and Water Pumping

Week 11: PV-Grid Interface - I

Week 12: PV-Grid Interface - II and Life Cycle Costing

Books and References

1. L. Umanand, *Design of Photovoltaic Systems*, www.amazon.in/dp/B0DCZYB2XP, Amazon Kindle Edition, 2024.

2. Chenming, H. and White, R.M., *Solar Cells from B to Advanced Systems*, McGraw Hill Book Co, 1983.

3. Ruschenbach, H.S., *Solar Cell Array Design Hand*, Varmostrand, Reinhold, NY, 1980.

4. Proceedings of IEEE Photovoltaics Specialists Conferences, *Solar Energy Journal*.

24EE710H - Power Electronics with Wide Band Gap Devices

About the Course

The major goal of this course is to familiarize the students with the properties of wide bandgap devices and designing driver boards to demonstrate the basic operating principles and their design in PCB and thermal distribution for real-world applications. Moreover, the modern design challenges associated with high-frequency power converter design, considering parasitic elements such as parasitic inductance and capacitance of the PCB, will also be presented. Power density advantages using these devices for high-power applications while operating at high frequency for emerging power applications are an integral part of the course. Additionally, methods of designing high-frequency magnetics for high-frequency operation of power converters will be introduced. Finally, the benefits of using these devices in real-life applications will be discussed. In brief, the objective of this course is to provide a detailed understanding of wide bandgap devices and the state-of-the-art of design of power converters for real life application using these devices.

Course Layout

Week 1: Introduction

Week 2: Wide Band Gap Devices

Week 3: Switching Characteristics

Week 4: Drivers for Wide Bandgap Devices

Week 5: Simulations of the WBG Devices

Week 6: Thermal Management of Power Converters

Week 7: High-Frequency Design Complexity

Week 8: High-Frequency PCB Designing

Week 9: Practical Design in KiCad/Altium

Week 10: Power Density Advantages

Week 11: Applications of Wide Bandgap Devices

Week 12: Application-based Simulation

Books and References

1. A. Lidow, J. Strydom, M. D. Rooij, D. Reusch, *GaN Transistors for Efficient Power Conversion*, Wiley, 2014, ISBN-13: 978-1118844762.

2. F. Wang, Z. Zhang, and E. A. Jones, *Characterization of Wide Bandgap Power Semiconductor Devices*, IET, ISBN-13: 978-1785614910.

3. G. Meneghesso, M. Meneghini, E. Zanoni, *Gallium Nitride-enabled High Frequency and High Efficiency Power Conversion*, Springer International Publishing, ISBN: 978-3-319-77993-5.

4. B.J. Baliga, *Gallium Nitride and Silicon Carbide Power Devices*, World Scientific Publishing Company (3 Feb. 2017).

5. L. Umanand and S. R. Bhat, *Design of Magnetic Components for Switched Mode Power Converters*, John Wiley Sons Australia, Limited, 1992.

6. L. Corradini, D. Maksimovic, P. Mattavelli, R. Zane, *Digital Control of High-Frequency Switched-Mode Power Converters*, Wiley, ISBN-13: 978-1118935101.

24EE710I - Nonlinear Dynamical Systems and Control

About the Course:

The course will provide an introduction to stability and control of nonlinear systems described by ordinary differential equations. The first part of the course will focus on the asymptotic analysis of nonlinear systems through Lyapunov function methods. The second part of the course will provide applications of the Lyapunov function approach to control of linear and nonlinear systems. The specific topics include robust control, adaptive control, and feedback linearization.

Course Layout:

Week 1: Introduction and preliminaries - Examples and definitions of nonlinear models; state and equilibrium; existence and uniqueness through examples.

Week 2: Existence and uniqueness of solutions, dependence on initial conditions.

Week 3: Stability Theory I - Lagrange, Lyapunov, and asymptotic stability, Lyapunov method and theorems.

Week 4: Stability Theory II - Invariant set theorems and Chetaev's theorem for instability.

Week 5: Linear Systems and Linearization.

Week 6: Construction of Lyapunov functions.

Week 7: Applications: Robust stability and Lure problem - Structured and sector uncertainties.

Week 8: Applications: Passivity and dissipativity - General theory, Applications to mechanical and electrical systems.

Week 9: Applications: Stable adaptive control - Estimation, indirect, and direct adaptive control.

Week 10: Applications: Lyapunov function theory for control problems - General form, specialization to linear systems, linearization, and cascade systems.

Week 11: Applications: Optimal control and inverse optimality.

Week 12: Applications: Model predictive control.

24EE710J - Introduction to Electric and Hybrid Electric Vehicles

About the Course:

Introduction to "Electric and Hybrid Electric Vehicles" offers a comprehensive understanding of the principles, technologies, and applications of electric mobility. This course is designed for students, professionals, engineers, and enthusiasts who seek to explore the rapidly evolving field of electric and hybrid electric vehicles (EVs and HEVs) and their pivotal role in sustainable transportation. Electric and hybrid electric vehicles represent a paradigm shift in the automotive industry, aiming to reduce carbon emissions, dependence on fossil fuels, and mitigate environmental impact. Through a series of engaging lectures, interactive assignments, quizzes, and discussions, participants will embark on a journey to explore the following key topics: By the end of the course, participants will have gained a holistic understanding of electric and hybrid electric vehicles, enabling them to contribute to the advancement of sustainable transportation solutions.

Course Layout:

Week 1: Overview of the Course, History, and Impact of EVs.

- Course Overview and History of Transportation and Vehicular Electrification.
- Vehicular Electrification Resurgence, Challenges, and Way Forward.
- Environmental, Social, and Economic Impact of Vehicular Electrification.

Week 2: Basic Vehicle Dynamics and Internal Combustion Engine (ICE) Vehicle.

- Vehicle Dynamics I and II.
- Overview of ICE and Characteristics.

Week 3: Basics of Electric Vehicle and Hybrid Electric Vehicle Configuration and Operation.

- ICE Vehicle and Electric Vehicle.
- Hybrid EV Configuration and Operation I, II, and III.

Week 4: Basics of Plug in HEV and Fuel Cell Vehicle and Comparison of different EVs and Fundamental of PHEV

- Plug-in Hybrid Electric Vehicle and Operation.
- Fundamentals of Hydrogen Fuel Cell Vehicle (FCV).
- Power Management and Comparison of EV Technologies.

Week 5: Fundamental of Electric Propulsion System and Constituent Technologies

- Overview of Electric Propulsion System and Components.
- Role of Power Electronics Converters in Electric Propulsion Systems.
- Electronic Control Units in EVs and HEVs.

Week 6: 6 Energy Source and Storage System for EVs and HEVs

- Battery Technologies and Management Systems.
- Ultracapacitor and Flywheel Technologies.
- Fuel Cell Technologies.

Week 7: Electric Motors and Control.

- Induction Motor and Control for EVs
- PMSM Motor and Control for EVs
- BLDC Motors and Control for EVs
- Switched Reluctance Motor and Control for EVs

Week 8: Introduction to EV Charging Systems.

- EV Charging Infrastructure in India.
- Types of EV Charging and their Architecture.
- Operation and Control of EV Charging Systems.

Week 9: Power Converter Configuration for EV Charging and RES Integration.

- AC-DC Converters with PFC for EV Charging
- DC-DC Converters with control for EV Charging
- Wireless EV Charging Systems.

Week 10: Thermal Management of EVs and HEVs.

- Guidelines for Thermal Management of EVs.
- Thermal Management of Batteries, Power Converters, and Motors.

Week 11: Policy, Standards, and Guidelines for Electrified Vehicles.

- Policies and Economics for Grid Integration.
- Charging Standards and Safety Guidelines.
- Battery Recycling and Safety Standards.

Week 12: Emerging Trends in EV Infrastructure.

- Business Models and Economics.
- Role of AI and V2X in the EV Sector.

Books and References

1. C.C. Chan and K.T. Chau, *Modern Electric Vehicle Technology*, Oxford University Press.

2. Ehsani, M., Gao, Y., Longo, S., and Ebrahimi, K., *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press, 2018.

3. Iqbal Husain, *Electric and Hybrid Vehicles: Design Fundamentals*, Third Edition, CRC Press, 2021.

4. Kumar, Lalit, and Shailendra Jain, *Electric Propulsion System for Electric Vehicular Technology: A Review*, Renewable and Sustainable Energy Reviews 29 (2014): 924–940.

5. F. R. Salmasi, *Control Strategies for Hybrid Electric Vehicles: Evolution, Classification, Comparison, and Future Trends*, IEEE Transactions on Vehicular Technology, vol. 56, no. 5, pp. 2393–2404, Sep. 2007.

6. G. Pistoia, Ed., *Lithium-Ion Batteries: Advances and Applications*, London, England: Elsevier Science, 2018.

7. Warner, John T., *The Handbook of Lithium-Ion Battery Pack Design: Chemistry, Components, Types, and Terminology*, Elsevier, 2024.

8. `Handbook for EV Charging Infrastructure Implementation`.

9. `E-AMRIT Reports and Articles`.

POOL II — COURSES SYLLABUS

24EE720A - Flexible AC Transmission Systems

Course Objectives

1. Study the importance of controllable parameters and benefits of FACTS controllers.
2. Design of Static Var Compensator and its applications to power systems.
3. Analyze the functional operation and control of series FACTS devices.
4. Describe the modeling, operation and control of VSC based FACTS devices.

UNIT I: Introduction

Review of basics of power transmission networks, control of power flow in AC transmission line, analysis of uncompensated AC transmission line. Passive reactive power compensation: effect of series and shunt compensation at the mid-point of the line on power transfer, need for FACTS controllers, types of FACTS controllers.

UNIT II: Static Var Compensator (SVC)

Configuration of SVC, voltage regulation by SVC, modeling of SVC for load flow analysis, modeling of SVC for stability studies. Design of SVC to regulate the mid-point voltage of a single-machine infinite bus (SMIB) system. Applications: transient stability enhancement and power oscillation damping of SMIB system with SVC connected at the mid-point of the line.

UNIT III: Thyristor and GTO Thyristor Controlled Series Capacitors

Concepts of controlled series compensation, operation of thyristor-controlled series capacitor (TCSC) and gate turn-off thyristor controlled series capacitor (GCSC). Analysis and modeling of TCSC and GCSC for load flow and stability studies. Applications of TCSC and GCSC.

UNIT IV: Voltage Source Converter Based FACTS Controllers

Static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), operation of STATCOM and SSSC. Power flow control with STATCOM and SSSC. Modeling of STATCOM and SSSC for power flow and transient stability studies. Operation of unified power flow controller (UPFC) and interline power flow controller (IPFC). Modeling of UPFC and IPFC for load flow and transient stability studies. Applications.

References

1. Mohan Mathur, R., Rajiv K. Varma, *Thyristor-Based FACTS Controllers for Electrical Transmission Systems*, IEEE Press and John Wiley & Sons, Inc, 2002.

2. K. R. Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International (P) Ltd., Publishers, New Delhi, Reprint, 2008.

3. Narain G. Hingorani, Laszio Gyugyl, *Understanding FACTS Concepts and Technology of Flexible AC Transmission System*, Standard Publishers, Delhi, 2001.

4. V. K. Sood, *HVDC and FACTS Controllers-Applications of Static Converters in Power System*, Kluwer Academic Publishers, 2004.

24EE720B - Advanced Power System Protection

Course Objectives

1. Implement various microprocessor-based relays.
2. Analyze and design static relay schemes.
3. Develop models of digital relays.
4. Apply AI methods to power system protection.

UNIT I: Microprocessor Based Relays

Basics of electromagnetic relays, their disadvantages and advantages. Microprocessor-based relays: overcurrent relay, impedance relay, directional relay, reactance relay, Mho relay, offset Mho relay.

UNIT II: Static Relays

Basic block diagram, advantages of static relays, comparators, phase and amplitude comparators. Operating principles: static overcurrent relays, differential relays, distance relays, pilot relaying and carrier current protection schemes, protection of transmission lines, three-zone protection schemes, carrier-aided distance schemes. Transformer protection, maloperation of relays, harmonic restraint relay.

UNIT III: Digital Relays

Developments in computer relaying, mathematical basis for protective relaying algorithms, differential equation-based technique, Fourier-based algorithms, wavelet transforms-based technique, numerical overcurrent protection, numerical distance protection, numerical differential protection.

UNIT IV: AI-Based Numerical Protection

Application of artificial neural networks (ANN) to overcurrent protection, application of ANN to transmission line protection, neural networks-based directional relay, ANN modular approach for fault detection, classification and location. ANN fuzzy-based approach for fault classification, power transformer protection based on ANN and fuzzy logic.

References

1. T. S. Madhava Rao, *Power System Protection – Static Relays*, TMH, 2010.
2. Badri Ram, *Power System Protection and Switchgear*, 2/e, TMH.
3. A. T. Johns and S. K. Salman, *Digital Protection for Power Systems*, 1995.

24EE720C - Battery Technology for Electrical Vehicles

Course Objectives

1. Understand electrical vehicle operation and battery basics.
2. Study the electric vehicle battery requirements and battery efficiency.
3. Explain electric vehicle battery charging methods.
4. Understand electric vehicle battery performance.

UNIT I: Electric Vehicle Operation and Battery Basics

Electric vehicle operation, lithium-ion battery basics, introduction to electric vehicle batteries, principles of operation of cell, batteries; electrochemical principles and reactions; factors affecting battery performance. Choice of a battery type for electric vehicles. Next-generation batteries: sodium-ion batteries and solid-state batteries (fundamental and working). Comparison among lithium-ion batteries, sodium-ion batteries, and solid-state batteries.

UNIT II: Battery Modeling

Testing the characteristics of lithium-ion batteries, battery modeling methods, simulation and comparison of equivalent circuit models, battery modeling method based on a battery discharging curve, battery pack modeling. State of charge (SOC), discussion on the estimation of SOC of a battery, battery SOC estimation algorithm. State of energy (SOE), estimation of battery SOE. State of health (SOH), estimation of SOH.

UNIT III: Battery Charging Technologies

Overview of lithium-ion battery charging technologies, different types of charging profiles, key indicators for measuring charging characteristics, charging external characteristic parameters of the lithium-ion battery, improvement of the constant current and constant voltage charging method.

UNIT IV: Battery Performance Management System

Battery performance management system (BPMS), thermal management system, BPMS charging control, high-voltage cabling and disconnects, safety in battery design, battery pack safety—electrolyte spillage and electric shock, electrical insulation breakdown detection, electrical vehicle component tests, building standards, ventilation. Battery recycling technologies: technology and economic aspects of battery recycling, secondary life of EV batteries.

Text Books

1. Jiang, Jiuchun, and Caiping Zhang, *Fundamentals and Applications of Lithium-Ion Batteries in Electric Drive Vehicles*, John Wiley & Sons, 2015.

2. Sandeep Dhameja, *Electric Vehicle Battery Systems*, Newnes Publishing, 2002.

3. Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.

ReferenceBooks:

1. Chris Mi, M. AbulMasrur, David Wenzhong Gao, Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, John Wiley Sons Ltd. , 2011

2. Tariq Muneer and Irene IllescasGarcía, "The automobile, In Electric Vehicles: Prospects and Challenges", Elsevier, 2017.

3. Chan, C. C., and K. T. Chau. Modern electric vehicle technology. Vol. 47. Oxford University Press on Demand, 2001.

24EE720D - Power Electronics Applications for Renewable Energy Systems

Course Objectives

- To provide knowledge about the stand-alone and grid-connected renewable energy systems.
- To equip with required skills to derive the criteria for the design of power converters for renewable energy applications.
- To analyze and comprehend the various operating modes of wind electrical generators and solar energy systems.
- To design different power converters, namely AC to DC, DC to DC, and AC to AC converters for renewable energy systems.
- To develop maximum power point tracking algorithms.

UNIT I: Introduction

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission). Qualitative study of different renewable energy resources: ocean, biomass, hydrogen energy systems. Operating principles and characteristics of solar PV, fuel cells, wind electrical systems—control strategy, operating area.

UNIT II: Electrical Machines for Renewable Energy Conversion

Review of reference theory fundamentals. Principle of operation and analysis of IG, PMSG, SCIG, and DFIG.

UNIT III: Power Electronics for Solar

Block diagram of solar photovoltaic system. Line commutated converters (inversion mode). Boost and buck-boost converters. Selection of inverter, battery sizing, array sizing. Standalone PV systems. Grid-tied and grid-interactive inverters. Grid connection issues.

UNIT IV: Power Electronics for Wind and Hybrid Renewable Energy Systems

Three-phase AC voltage controllers. AC-DC-AC converters: uncontrolled rectifiers, PWM inverters, matrix converters. Standalone operation of fixed and variable-speed wind energy conversion systems. Grid connection issues. Grid-integrated PMSG and SCIG-based WECS. Need for hybrid systems. Range and type of hybrid systems. Case studies of Wind-PV maximum power point tracking (MPPT).

Textbooks

1. Rashid M. H., *Power Electronics Handbook*, Academic Press, 2001.

2. P.S. Bimbhra, *Power Electronics*, Khanna Publishers, 3rd Edition, 2003.

3. Rai G.D., *Non-conventional Energy Sources*, Khanna Publishers, 1993.

4. Rai G.D., *Solar Energy Utilization*, Khanna Publishers, 1993.

5. R. Seyezhai and R. Ramaprabha, *Power Electronics for Renewable Energy Systems*, Scitech Publications, 2015.

References

1. Gray L. Johnson, *Wind Energy System*, Prentice Hall, 1995.

2. B.H. Khan, *Non-conventional Energy Sources*, Tata McGraw-Hill Publishing Company.

3. Fang Lin Luo and Hong Ye, *Renewable Energy Systems*, Taylor Francis Group, 2013.

4. S.N. Bhadra, D. Kastha, and S. Banerjee, *Wind Electrical Systems*, Oxford University Press, 2009.

24EE720E - Analysis and Design of Inverters

Course Objectives

- To provide the electrical circuit concepts behind the different working modes of inverters to enable a deep understanding of their operation.
- To equip with required skills to derive the criteria for the design of inverters for UPS, drives, etc.
- To analyze and comprehend the various operating modes of different configurations of inverters.
- To design different single-phase and three-phase inverters.
- To impart knowledge on multilevel inverters and modulation techniques.

UNIT I: Single Phase Inverters

Principle of operation of half and full bridge inverters. Performance parameters. Voltage control of single-phase inverters using various PWM techniques. Various harmonic elimination techniques. Forced commutated thyristor inverters.

UNIT II: Three Phase Inverters

180-degree and 120-degree conduction mode inverters with star and delta connected loads. Voltage control of three-phase inverters: single, multi-pulse, sinusoidal, space vector modulation techniques. Application to drive systems.

UNIT III: Multilevel Inverters

Multilevel concept: diode clamped, flying capacitor, cascade type multilevel inverters. Comparison of multilevel inverters. Application of multilevel inverters. PWM techniques for MLI. Single-phase and three-phase impedance source inverters.

UNIT IV: Resonant Inverters and Power Conditioners

Series and parallel resonant inverters. Voltage control of resonant inverters. Class E resonant inverter. Resonant DC-link inverters. Power line disturbances. Power conditioners. UPS: offline UPS, online UPS.

Textbooks

1. Rashid M. H., *Power Electronics Circuits, Devices, and Applications*, Prentice Hall India, Third Edition, 2004.

2. P.S. Bimbhra, *Power Electronics*, Khanna Publishers, Eleventh Edition, 2003.
3. Ned Mohan, T. M. Undeland, and W. P. Robbin, *Power Electronics: Converters, Application, and Design*, Wiley India Edition, 2006.
4. Bimal K. Bose, *Modern Power Electronics and AC Drives*, Pearson Education, Second Edition, 2003.

References

1. Philip T. Krein, *Elements of Power Electronics*, Oxford University Press, 1998.
2. P.C. Sen, *Modern Power Electronics*, Wheeler Publishing Co., First Edition, 1998.
3. Jai P. Agrawal, *Power Electronics Systems*, Pearson Education, Second Edition, 2002.

24EE720F - Solar Energy Engineering and Technology

About the Course

The course content is designed to provide comprehensive knowledge on solar radiation, analysis of solar radiation data, fundamentals of the solar thermal and photovoltaic system along with storage of energy required for effective design of efficient solar energy conversion devices. The concepts will be illustrated with practical examples, schematics, and block diagrams wherever required. A sufficient number of numerical problems with solutions will be discussed in the course. This course is specifically designed for undergraduate and postgraduate students of Energy Engineering and Technology. Further, the course will be very much useful for students and researchers from varied academic backgrounds for the synthesis of novel energy conversion devices and processes.

Course Layout

Week 1: Energy Scenario, overview of solar energy conversion devices and applications, physics of propagation of solar radiation from the sun to earth.

Week 2: Sun-Earth Geometry, Extra-Terrestrial and Terrestrial Radiation, Solar energy measuring instruments.

Week 3: Estimation of solar radiation under different climatic conditions, Estimation of total radiation.

Week 4: Fundamentals of solar PV cells, principles and performance analysis, modules, arrays, theoretical maximum power generation from PV cells.

Week 5: PV standalone system components, Standalone PV-system design.

Week 6: Components of grid-connected PV system, solar power plant design and performance analysis.

Week 7: Fundamentals of solar collectors, Snail's law, Bouger's law, Physical significance of Transmissivity–Absorptivity product.

Week 8: Performance analysis of Liquid flat plate collectors and testing.

Week 9: Performance analysis of Solar Air heaters and testing.

Week 10: Solar thermal power generation (solar concentrators).

Week 11: Thermal energy storage (sensible, latent, and thermochemical) and solar pond.

Week 12: Applications: Solar refrigeration, Passive architecture, solar distillation, and emerging technologies.

Books and References

1. G. N. Tiwari, *Solar Energy: Fundamentals, Design, Modeling, and Applications*, Narosa, 2002.
2. S. P. Sukhatme and J. K. Nayak, *Solar Energy: Principles of Thermal Collection and Storage*, Tata McGraw-Hill, 2006.
3. C. S. Solanki, *Solar Photovoltaics: Fundamentals, Technologies, and Applications*, Prentice Hall India, 2nd Edition, 2011.
4. J. A. Duffie and W. A. Beckman, *Solar Engineering of Thermal Processes*, John Wiley, 2006.
5. D. Y. Goswami, F. Kreith, and J. F. Kreider, *Principles of Solar Engineering*, Taylor and Francis, 1999.
6. H. P. Garg and J. Prakash, *Solar Energy: Fundamentals and Applications*, Tata McGraw-Hill, 1997.
7. M. A. Green, *Third Generation Photovoltaics: Advanced Solar Energy Conversion*, Springer, 2003.
8. A. Goetzberger and V. U. Hoffmann, *Photovoltaic Solar Energy Generation*, Springer, 2010.
9. K. Jager, O. Isabella, A. H. M. Smets, R. A. C. M. M. Van Swaaij, and M. Zeman, *Solar Energy – Fundamentals, Technology, and Systems*, Delft University of Technology, 2014.
10. T. C. Kandpal and H. P. Garg, *Financial Evaluation of Renewable Energy Technologies*, McMillan India Ltd., 2013.

24EE720G - Distributed Optimization and Machine Learning

About the Course

Centralized access to information and its subsequent processing is often computationally prohibitive over large networks due to communication overhead and the scale of the problem. Consequently, such systems rely on control and optimization algorithms that are fully distributed or even decentralized in nature. This course will provide a comprehensive overview of the design and analysis of distributed optimization algorithms and their applications to machine learning. The aim is to revisit classical control and optimization algorithms for centralized optimization and discuss how these can be extended to a distributed setting to accommodate the effects of communication constraints, network topology, computational resources, and robustness. Topics include graph theory, iterative methods for convex problems, synchronous and asynchronous setups, consensus algorithms, and distributed machine learning. We will also explore some recent literature in this area that exploits control theory for the design of accelerated distributed optimization algorithms.

Course Layout

- **Week 1:**
  - Introduction to Distributed Optimization
  - Mathematical Optimization, Convex Sets, and Convex Functions
- **Week 2:**
  - Strong Convexity and Its Implications
  - Constrained Optimization Problems: Primal and Lagrangian Dual
- **Week 3:**
  - KKT Conditions and Primal/Dual Methods
  - Analysis of Gradient Descent
- **Week 4:**
  - Analysis of Accelerated Optimization Algorithms
  - Optimization Algorithms as Dynamical Systems and Introduction to Stability Theory
- **Week 5:**
  - Lyapunov Analysis of Gradient Flows

  - Gradient Flows for Equality Constrained Optimization and Saddle-Point Problems

- **Week 6:**
  - Accelerated Gradient Flows
  - Augmented Lagrangian and Method of Multipliers
- **Week 7:**
  - ADMM (Alternating Direction Method of Multipliers)
  - Dual Ascent and Dual Decomposition
- **Week 8:**
  - Introduction to Graph Theory
  - Distributed Consensus
- **Week 9:**
  - Continuous-Time Analysis of Consensus Algorithms
  - Distributed Optimization Problem (Economic Dispatch Problem)
- **Week 10:**
  - Distributed Optimization Algorithms
  - Introduction to Neural Networks and Ring-Allreduce Algorithm
- **Week 11:**
  - Introduction to Federated Learning
  - Data Heterogeneity in Federated Learning
- **Week 12:**
  - Computational Heterogeneity in Federated Learning
  - Robustness in Federated Learning

Books and References

1. Boyd, Stephen P., and Lieven Vandenberghe. *Convex Optimization*. Cambridge University Press, 2004.

2. Nedić, A. (2018). *Distributed Optimization Over Networks*. In: Facchinei, F., Pang, J.S. (eds) Multi-agent Optimization. Lecture Notes in Mathematics, vol 2224. Springer, Cham. https://doi.org/10.1007/978-3-319-97142-1_1.

24EE720H - Power Electronics Applications in Power Systems

ABOUT THE COURSE

Electrical power system is growing very fast in a country like India. Thus, the operation of electrical power system becomes more and more complex. To enhance the reliability and to have faster control, there needs power electronics-based devices. There are various NPTEL courses to understand the basic electrical power systems. There are some advanced power system courses, as well. Similarly, there are few basic and advance power electronics courses. The Flexible AC Transmission Systems, popularly known with the acronym FACTS, provide the power electronics based solutions to enhance the capability of electrical power transmission systems. This course focuses the application of these power electronics based solutions in power systems. The course will start with the recapitulation of some basic concepts and modelling of electrical power transmission systems. Then, the mathematical modelling of various FACTS devices will be discussed. Then, the applicability of those devices in mitigating various problems of power transmission systems and in enhancing the performances of power transmission systems will be discussed in details.

Course Layout

Week 1: Introduction

- Introduction
- Active and reactive power in electrical circuits
- Reactive power compensation

Week 2: Long transmission line modelling

- Transmission line modelling: Categorization
- Derivation of the relation of sending and receiving end voltages and currents
- Concept of surge impedance, phase constant, and symmetrical lines

Week 3: Power flow in Long transmission lines

- Derivation of the expressions of active and reactive power
- Numerical Example

Week 4: Mid-point compensation of transmission lines

- Expressions of the voltage and current at the mid-point
- Mid-point compensation with numerical examples – I
- Mid-point compensation with numerical examples – II
- Series and Shunt compensations

Week 5: Static VAR Compensator (SVC): Part-I

- Different types of SVC: Thyristor controlled Reactor (TCR) – I
- Different types of SVC: Thyristor controlled Reactor (TCR) – II
- Different types of SVC: Fixed capacitor TCR and Mechanically switched capacitor TCR

Week 6: Static VAR Compensator (SVC): Part-II

- Different types of SVC: Thyristor switched capacitor (TSC)
- Different types of SVC: TSC-TCR
- Numerical examples

Week 7: Applications of SVC in power systems - I

- Application of SVC in power system voltage control
- Numerical Example

Week 8: Applications of SVC in power systems - II

- Application of SVC in enhancing power system stability
- Application of SVC in power system damping

Week 9: Thyristor controlled series capacitor (TCSC) - I

- Basic mathematical modelling – I
- Basic mathematical modelling – II

Week 10: Thyristor controlled series capacitor (TCSC) - II

- Application of TCSC in power systems – I
- Application of TCSC in power systems – II

Week 11: Static Synchronous compensator (STATCOM)

- Basic mathematical modelling
- Applications of STATCOM in power systems

Week 12: Static synchronous series capacitor (SSSC)

- Basic mathematical modelling
- Applications of SSSC in power systems

Books and References

1. R. M. Mathur and R. K. Varma, *Thyristor-Based FACTS Controllers for Electrical Transmission Systems*, Wiley-IEEE Press, 2011.
2. N. G. Hingorani, L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, Wiley, 2012 (reprint).
3. K. R. Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International (P) Limited, 2021 (reprint).

24EE720I - Hydrogen Energy: Production, Storage, Transportation and Safety

ABOUT THE COURSE

The course will comprehensively cover all the aspects of the hydrogen energy value chain including production methods from hydrocarbons & renewables, separation & purification, storage, transportation & distribution, refueling, utilization in various sectors, associated energy conversion devices, sensing, and safety. Technical comparisons of various processes and technologies, economic aspects & cost analysis, regulations, codes and standards, global status, and future directions will be discussed. The course will provide a broad knowledge of hydrogen as an energy carrier, the way it will play an important role in various sectors towards decarbonization, current limitations, and future scenarios.

Course Layout:

- **Week 1:** Properties of hydrogen, global status of supply and demand, methods of hydrogen production, steam reforming, tutorial
- **Week 2:** Advanced methods of steam reforming, partial oxidation, autothermal reforming, combined reforming, reforming using alternate energy sources, tutorial
- **Week 3:** Hydrogen production from methane decomposition, from coal and biomass, tutorial
- **Week 4:** Hydrogen separation and purification, thermochemical cycles for hydrogen production, fundamentals for electrolysis of water
- **Week 5:** Components of electrolytic cell, configuration of electrolyzer stack, different electrolyzer technologies, photoelectrochemical hydrogen production, technical and economic comparison of different production methods and global status, cost analysis, tutorial
- **Week 6:** Introduction to hydrogen storage, underground hydrogen storage, fundamentals of hydrogen compression and expansion
- **Week 7:** Mechanical and non-mechanical hydrogen compressors; compressed hydrogen tank types and design considerations, tutorial
- **Week 8:** Hydrogen liquefaction, liquid state hydrogen storage tanks, fundamentals of hydrogen storage in adsorption based materials

- **Week 9:** Fundamentals and thermodynamics of absorption based hydrogen storage, metal hydrides, types of metal hydrides, metal hydride based systems design, tutorial
- **Week 10:** Novel materials for solid state hydrogen storage; economics of storage; long-distance hydrogen transport via pipelines, ships and in form of LOHC; hydrogen transport via road; hydrogen refueling stations
- **Week 11:** Use of hydrogen in internal combustion engines, fuel cells, hydrogen sensing
- **Week 12:** Properties of hydrogen associated with hazards, classification of hydrogen hazards, compressed and liquid hydrogen related hazards, regulation, codes and standards, utilization of hydrogen in various sectors, global status and future directions

Books and References:

1. Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009.
2. Global Hydrogen Review 2021, IEA (2021), Paris, https://www.iea.org/reports/global-hydrogen-review-2021
3. Agata Godula-Jopek, Hydrogen Production by Electrolysis, Wiley-VCH, Germany, 2015.
4. Tzimas, E., Filiou, C., Peteves, S.D., & Veyret, J.B., *Hydrogen storage: state-of-the-art and future perspective*, Netherlands: European Communities, 2003.
5. Michael Hirscher, *Handbook of Hydrogen Storage*, Wiley-VCH, 2010.

24EE720J - Machine Learning and Deep Learning - Fundamentals and Applications

ABOUT THE COURSE

In this course, we will start with traditional Machine Learning approaches, e.g., Bayesian Classification, Multilayer Perceptron, etc., and then move to modern Deep Learning architectures like Convolutional Neural Networks, Autoencoders, etc. We will learn about the building blocks used in these Deep Learning-based solutions. Specifically, we will learn about feedforward neural networks, convolutional neural networks, recurrent neural networks, and attention mechanisms. On completion of the course, students will acquire the knowledge of applying Machine and Deep Learning techniques to solve various real-life problems.

Course Layout:

- **Week 1:** Introduction to ML, Performance Measures, Bias-Variance Trade-off, Linear Regression.
- **Week 2:** Bayes Decision Theory, Normal Density and Discriminant Function, Bayes Decision Theory - Binary Features, Bayesian Belief Network.
- **Week 3:** Parametric and Non-Parametric Density Estimation –ML and Bayesian Estimation, Parzen Window and KNN.
- **Week 4:** Perceptron Criteria, Discriminative Models, Support Vector Machines (SVM).
- **Week 5:** Logistic Regression, Decision Trees, Hidden Markov Model (HMM).
- **Week 6:** Ensemble Methods –Ensemble Strategies, Boosting and Bagging, Random Forest.
- **Week 7:** Dimensionality Problem, Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA).
- **Week 8:** Concept of Mixture Model, Gaussian Mixture Model, Expectation Maximization Algorithm, K-Means Clustering.
- **Week 9:** Fuzzy K-Means Clustering, Hierarchical Agglomerative Clustering, Mean-Shift Clustering.
- **Week 10:** Neural Network –Perceptron, Multilayer Network, Backpropagation, RBF Neural Network, Applications.

- **Week 11:** Introduction to Deep Learning, Convolutional Neural Networks (CNN), Vanishing and Exploding Gradients in Deep Neural Networks, LeNet-5, AlexNet, VGGNet, GoogleNet, and ResNet.

- **Week 12:** Recent Trends in Deep Learning –Generative Adversarial Networks (GAN), Autoencoders and Relation to PCA, Recurrent Neural Networks, U-Net, Applications and Case Studies.

Books and References:

1. E. Alpaydin, *Introduction to Machine Learning*, 3rd Edition, Prentice Hall (India), 2015.

2. R. O. Duda, P. E. Hart, and D. G. Stork, *Pattern Classification*, 2nd Edn., Wiley India, 2007.

3. C. M. Bishop, *Pattern Recognition and Machine Learning (Information Science and Statistics)*, Springer, 2006.

4. M.K. Bhuyan, *Computer Vision and Image Processing: Fundamentals and Applications*, CRC Press, USA, 2019.

5. S. O. Haykin, *Neural Networks and Learning Machines*, 3rd Edition, Pearson Education (India), 2016.

6. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, MIT Press, 2016.

7. Michael A. Nielsen, *Neural Networks and Deep Learning*, Determination Press, 2015.

8. Yoshua Bengio, *Learning Deep Architectures for AI*, Now Publishers Inc., 2009.