Course title: Electric Vehicle, Energy Storage System and Hydrogen technologies

Course code: ENR 166	**No. of credits:** 3	**L-T-P:** 38-7-0	**Learning hours:** 45

Pre-requisite course code and title (if any): N/A

Department: Sustainable Engineering

Course coordinator: Prof Naqui Anwer	**Course Instructor:** Prof. Naqui Anwer/ Prof. S C Mullick/ Prof. D K Sharma

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Course type: Core	**Course offered in:** Semester 2

Course description

This course is designed to provide a comprehensive understanding about electric vehicles, energy storage systems and hydrogen technologies. These three technologies are contemporary technologies contributing actively towards sustainable development. The use of electric vehicle for transportation and use of energy storage system in utility scale RE plants for improving stability and enhancing reliability is going to increase in the days to come. The hydrogen is rapidly being accepted as an alternate fuel and producing it using RE makes it even more lucrative. This course will provide an in-depth knowledge of these three important emerging filed covering technologies, management and their applications.

Course objective

- Recognize EV/HEV technical and economic objectives. Identify efficient EV/HEV architectures.
- Explain the mechanism of battery and motors in terms of functionality, control, and integration.
- Describe a basic coordinated control between different parts of EV.
- To study details of various energy storage systems along with applications
- Enabling to identify the optimal solutions to a particular energy storage application/utility.
- To provide comprehensive and logical knowledge of hydrogen production, storage and utilization

Course contents

Module	Topic	L	T	P
1	**Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) Developments:** Historical developments, recent developments, National Electric Mobility Mission Plan (NEMMP). Policies and regulations for EV adoption, Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) Scheme. State of art EVs and HEVs, EV configurations, EV parameters, HEV configurations, Power flow control. **Electric Propulsion:** Different types of power converter based DC motor drives, induction motor drives, permanent magnet motor drives, Switched reluctance motor drives. **Energy Sources:** Basics- Parameters-Capacity, Discharge rate, State of charge, state of Discharge of Batteries, Fuel cells, Ultra-capacitors, Flywheels. **EV auxiliaries:** EV charging standards like CCS, ChaDeMo (Japanese), GB/T (Chinese), Bharat AC-001 and DC-001 and other BIS standards; Battery characteristics and chargers, Battery indication and management, Temperature control units, Power steering units, Auxiliary power supplies, Navigation systems, Regenerative Braking systems. Safety aspects.	16	0	0
2	**Necessity and types of energy storage system:** Necessity of energy storage, policy and regulatory developments in energy storage, recent standards for energy storage systems - MESA, IEC, IEEE. Different types of energy storage – mechanical, chemical, electrical, electrochemical, biological, magnetic, electromagnetic, and thermal. Comparison of energy storage technologies. **Energy Storage Systems:**	10	4	0

	Thermal energy storage, sensible and latent heat, phase change materials, Energy and exergy analysis of thermal energy storage, electrical energy storage-super-capacitors, magnetic energy storage-superconducting systems, Mechanical-Pumped hydro, flywheels and pressurized air energy storage, Chemical-Hydrogen production and storage, Principle of direct energy conversion using fuel cells, thermodynamics of fuel cells, Types of fuel cells, AFC, PEMFC, MCFC, SOFC, Microbial fuel cell, Fuel cell performance, Electrochemical Energy Storage- Cell design - principles of "anode, cathode and electrolyte", Construction and operation of Battery Storage Systems-primary, secondary and flow batteries.			
3	**Hydrogen energy systems:** Policies and regulations for promotion of hydrogen, National Green Hydrogen Mission. Concept of grey, blue and green hydrogen; Properties of hydrogen as fuel, Hydrogen pathways, Introduction-current uses, general introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants **Hydrogen production processes:** Thermal-Steam reformation, thermo-chemical water splitting, gasification-pyrolysis, nuclear thermal catalytic and partial oxidation methods. Electrochemical- Electrolysis, photo electro chemical method. **Hydrogen storage and safety:** Physical and chemical properties, general storage methods, compressed storage-composite cylinders, metal hydride storage, carbon based materials for hydrogen storage. Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles.	12	3	0
	Total	**38**	**7**	**0**

Evaluation criteria

Minor test 1: 20% (at the end of module 1)
Minor test 2: 20% (at the end of module 2)
Assignment: 10% (at the end of module 1, 2 & 3)
Major test: 50% (at the end of the semester)

Learning outcomes

After completing the course, the students will be able to:

- Learn fundamentals of advanced batteries, super-capacitors and fuel cells for electrification of vehicles.
- Learn hybridization of various energy conversion devices for vehicle electrification.
- Understand battery management systems and state-of-charge estimation.
- Understand the overall operation of Electric vehicles.
- The student will be able to cope up with upcoming technologies in the energy storage systems.
- Minimize environmental hazards associated with the use of hydrogen storage and fuel cell technology

Pedagogical approach

A combination of class-room interactions, expert lecture, assignment, tutorial, practical and case study

Reference Books:

1. C. C. Chan, K. T. Chau, "Modern Electric Vehicle Technology" published by Oxford University Press, 2001.
2. Rodrego Garcia-valle and J. A. P Lopes "Electric Vehicle Integration into Modern Power Networks" Springer, 2012.
3. Chris Mi and M. Abul Masrur, "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives" John Wiley Ltd. Publication, 2017.
4. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, "Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design" CRC Press, 2004.
5. S. P. Sukhatme and J K Nayak, Solar Energy: Principles of thermal collection and storage, Tata McGraw-Hill, 2009.
6. H. P. Garg, S. C. Mullick and A. K. Bhargava, Solar Thermal Energy Storage, Springer, 1985.
7. Michael Hirscher, Hand Book of Hydrogen Storage, Wiley-VCN Verlag GmbH, 2010.
8. A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN – 978-1-84919-219-4), 2011.

9. Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt," Energy Storage in Power Systems" Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016.
10. A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN – 13:9789380090122), 2011.
11. Energy Storage - Technologies and Applications by Ahmed Faheem Zobaa, InTech, 2013.
12. Fundamentals of Energy Storage by J. Jensen and B. Sorenson, Wiley-Interscience, New York, 1984.
13. Thermal energy storage: Systems and Applications by Dincer I. and Rosen M. A., Wiley pub, 2010.

Additional information (if any): NA

Student responsibilities

Adopt peer learning and knowledge sharing within the class, attendance, feedback, discipline: as per university rules

Course Reviewer

Dr Shashank Vyas, Senior Associate Consultant (Energy and Utilities), Infosys

Dr Odne Stokke Burheim, Professor, Department of Energy and Process Engineering. NTNU, Norway