Course Title: Energy Storage Systems (EN) [3-0-0-6]

Introduction to Energy Storage: Relevance and scenario. Perspective on development of Energy storage systems. Energy storage criteria, General concepts. Conventional batteries – fundamentals and applications. Grid connected and Off grid energy storage systems and requirements.
Thermal storage: Thermal properties of materials, Principle of operations, Efficiency factors, large scale and Medium scale operations, Pros and Cons. Advances in thermal storage.
Mechanical Storage: Types of systems, Principle of operations, Emerging advances and Technologies. case study : Flywheel
Electrochemical Storage: Materials, Principle of Operation, Challenges and research survey, Positive electrode materials, negative electrode materials, electrolytes.
Fuel Cells and Hydrogen storage: Principle of operation, challenges and Case studies
Magnetic storage: Principle of operation, emerging challenges, devices and technology review
Electro-optic and Optical storage: Principles of operation, device fabrication, emerging devices and upcoming technologies
Supercapacitors: Principle of operation, device fabrication, challenges and technical review

Text/Reference Book

[1] Energy Storage 2010th Edition by Robert Huggins (Author)
[2] Lithium-Ion Batteries: Fundamentals and Applications (Electrochemical Energy Storage and Conversion) by Yuping Wu (Editor)
[3] Storing Energy: with Special Reference to Renewable Energy Sources by Trevor M. Letcher (Author)
[4] Electrochemical Energy Storage for Renewable Sources and Grid Balancing by Patrick T. Moseley (Editor), Jürgen Garche (Editor)
[5] Nanomaterials for Energy Conversion and Storage by Dunwei Wang (Editor), Guozhong Cao (Editor)

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EN672: Energy Engineering: A Fundamental Approach (3-0-0-6)

Course Content:

Part-I: Fundamentals of Thermo-Fluid and electrical systems

Thermodynamics: Review of 1st, 2nd and 3rd law of thermodynamics; properties of pure substance; phychrometrics; throttling process; refrigeration cycles; reactive systems; gas power cycles.

Fluid mechanics: Review of fundamental concepts; scale of pressure measurement; barometer; manometer; mass, momentum and energy equations and its applications; boundary layer concepts; analysis of turbo machines: compressors, fans and blowers.

Heat and Mass Transfer: Modes of heat transfer: conduction, convection and radiation; boiling and condensation; heat exchangers and its performance parameters; basics principles of mass transfer.

Basic electrical engineering: Fundamentals of electrical engineering; Kirshoff's law; amperes law; power factor; electrical machines: motor (DC, induction, synchronous), generators, transformers.

Part-II: Renewable Energy Systems

Energy conservation: First law efficiency; second law efficiency; vapour power cycles: Rankine cycle, binary cycle, cogeneration, combined cycle; energy savings; carbon footprint; greenhouse gas; energy audit.

Energy conversion: Solar energy conversion: Solar thermal and Photovoltaic, bioenergy conversion: biochemical, electrochemical and thermochemical; biofuels; wind energy conversion; principles of fuels and combustion; combustion devices; principles of drying; hydro-electric power; fuel cells; fission and fusion reaction; comparison of energy conversion processes.

Texts/References:

1. P. K. Nag, *Engineering Thermodynamics,* Tata McGraw Hill, 2nd Edition, 1996.
2. G. N. Tiwari, *Solar Energy, Fundamentals, Design, Modeling and Applications*, Narosa, 2002.
3. S. P. Sukhatme and J. K. Nayak, *Solar Energy: Principles of Thermal Collection and Storage*, Tata McGraw Hill, 2006.
4. C. S. Solanki, *Solar Photovoltaics: Fundamentals, Technologies and Applications,* Prentice Hall India, 2nd Edition, 2011.
5. H. P. Garg and J. Prakash, *Solar Energy: Fundamentals and Applications*, Tata McGraw Hill, 1997.
6. S. K. Som, Gautam Biswas, and Suman Chakraborty, *Introduction to Fluid Mechanics and Fluid Machines*, McGraw Hill, 3rd Edition, 2012.
7. M. Necati Ozisik, *Heat Transfer A basic Approach*, McGraw Hill International Editions, 1985.
8. Samir Sarkar, Fuels and Combustion, Universities Press, 3rd Edition, 2009.
9. C.L. Wadhwa, Basic Electrical Engineering, New Age International, 4th edition, 2007.

EN 661: Renewable Energy Systems [3-0-0-6]

Unit 1: Introduction

- Overview of Global and Indian energy scenario
- Sources of Energy and its classifications
- Renewable energy sources, classification and systems
- Overview of 1st , 2nd and 3rd law of thermodynamics
- Thermodynamic processes and basic cycles

Unit 2: Bioenergy

- Introduction to biofuels
- Feedstocks for biofuel production
- Biodiesel, bioethanol, biobutanol, biohydrogen
- Biochemical and thermochemical conversions of biomass

- Concept of biorefinary
- Fuel cell: importance, classification, basic principle design, materials used for developing fuel cells, applications and future prospects

Unit 3: Solar Energy Conversion

- Solar thermal energy conversion devices
- Solar energy storage and applications
- Solar cell fundamentals
- Solar cell technologies and PV systems
- Solar energy assisted heating and cooling systems

Unit 4: Wind Energy Conversion
- Fundamentals of wind energy conversion
- Types of wind energy conversion devices
- Mathematical derivation of Betz limit

Unit 4: Hydropower
- Fundamentals of Mini/micro-hydel systems

Unit 5: Non- conventional method of energy conversion

- Magneto hydrodynamics (MHD)
- Thermoelectric generator
- Thermionic generator
- Thermo nuclear fusion

Unit 6: Wave, OTEC, geothermal energy
- Wave energy conversion, geothermal energy and ocean thermal energy conversion

Text Book

- Nag P.K., Thermodynamics (1996), **Tata McGraw Hill**
- Garg H. P. and Prakash S. (1997); *Solar Energy: Fundamental and Application*, **Tata McGraw Hill**
- Mohammad Omar Abdullah (2012); *Applied Energy: An Introduction,* **CRC Press**
- B H Khan (2014); Non-Conventional Energy Resources, 2nd Edition, **McGraw Hill Education**
- Solanki C. S. (2009); *Solar Photovoltaics: Fundamentals, Technologies and Applications*, Prentice Hall India
- Nag P.K., Power Plant Engineering (2002), **Tata McGraw Hill Education**.

EN 663: Operation and Instrumentation [1-0-4-6]

Course content/ Title of the practical classes

[1] Evaluation of Calorific Value using Oxygen Bomb Calorimeter
[2] Performance testing of an IC engine set-up
[3] I-R Characteristics of a Silicon Cell PV Module
[4] Calibration of a Copper-Constantan Thermocouple
[5] Calibration of a Pressure Transducer
[6] Proximate Analysis of Biomass
[7] Thermo-Gravimetric Analysis of a Solid Fuel
[8] UV Vis Spectrophotometric analysis of enzymes applied for waste to energy conversion
[9] Analysis of Power Potential of a Fuel cell

[10] Microscopic analysis of bacterial population for waste to energy
[11] Analysis of Fatty Acid profile of a Biofuel (HPLC)
[12] Operation and Functioning of Biochemical Conversion
[13] Gas Chromatograph operation and analysis of Gas composition