Birla Institute of Technology & Science, Pilani
Hyderabad Campus

SECOND SEMESTER 2023-2024

Course Handout Part II

Date: 09-01-2024

In addition to part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

Course No. : EEE/ECE/INSTR F428

Course Title : **Energy Storage Systems**

Instructor-in-Charge : **Dr. Ankur Bhattacharjee**

Scope and Objective of the Course:

Familiarization with various energy storage technologies, their working principle, design and applications in renewable energy domain, electric vehicles and other power supply systems.

Textbooks:

1. Energy Storage and Conversion: Materials and Devices, Ashok Kumar, Shyamal Kumar Das, Narosa Publishing House.
2. Energy Storage: Systems and Components, Alfres Rufer, CRC Press.
3. Energy Storage: Fundamentals, Materials and Applications, Huggins, Robert, Springer.
4. Linden's Handbook of Batteries, Kirby W. Beard, The Mcgraw Hill publisher.

Reference books

1. Energy Storage Devices for Electronic Systems, Nihal Kularatna, Elsevier.
2. Advances in Batteries for Medium and Large-Scale Energy Storage, C Menictas M Skyllas-Kazacos T M Lim, Woodhead Publishers.
3. Handbook on Battery Energy Storage System, Asian Development Bank (ADB).

Course Plan:

Lecture No.	Learning objectives	Topics to be covered	Chapter in the Text Book
1	To familiarize with the need of energy storage and different energy storage technologies	Need of Energy Storage. Broad Classification of Energy Storage Systems, Primary and Secondary Energy Storages and their applications.	**TB1,TB2**
2	To know the electrochemical properties and principles	Electrochemical principles: Electrochemical Redox, Oxidation-reduction half cells	**TB1,TB2**
3	To know about different types of	Galvanic Cells, Simple Voltaic Cell, Reversible and Irreversible Cells	**TB1,TB2**

	electrochemical cells		
4	To learn about the parameters related to electrode	Electrode potential, Factors affecting electrode potentials, Reversible electrode (standard electrodes)	**TB1,TB2**
5	To get familiarized with electrode chemistry	Nernst Potential Equation, Electrode reactions and Cell Chemistry	**TB1,TB2**
6	To learn about the electrode reactions	Nature of the electrode reaction, Electron Transfer, Mass transport, Fick's Law, Impedance spectroscopy.	**TB1,TB2**
7	To know battery energy storage	Batteries: Primary and secondary batteries: Pb-Acid, Li-ion, NiCd, NaS, Redox Flow (RFBs), Advanced batteries, Operation of a battery cell	**TB1,TB3**
8	To learn about the operating parameters of the batteries	Theoretical cell voltage, capacity and energy, specific energy and energy density of a battery	**TB1,TB3**
9	To know the charging and discharging of batteries	Mode of battery charge and discharge, electrical characteristic under different rate of charge-discharge operations, Round-Trip efficiency of battery	**TB3,RB3**
10	To learn about the operational features of the batteries	Thermal behavior of batteries during charge and discharge, Battery service life, Battery Aging, Operation and maintenance, Battery safety issues, Recycling	**TB1,TB3, RB3**
11	To familiarize with the Battery Standards	Battery Standards: International Standards, Concept of Standardization, IEC and ANSI nomenclature	**TB1,TB3, RB3**
12	To know about the performance of Battery storage	Rechargeable battery, Electrical performance, Regulatory and Safety standards.	**TB1,TB3**
13	To design battery stack	Battery stack design, its engineering aspects	**TB3, RB3**
14	To design battery Charge Controller	Charge controller design: different charging algorithms	**TB3, RB3**
15	To know about the stationary and portable applications of battery storage	Off-Grid and On-Grid applications of battery storage, Application oriented choice of batteries	**TB3, RB3**
16	To know the Power Electronic Components associated with Battery storage interfacing	Power Electronic Converters for interfacing Batteries with power systems, Integration with renewable energy sources	**TB3, RB3**

17	To design and control the battery performance parameters	Battery Management Systems (BMS)	**TB3, RB3**
18	To learn battery performance for small, medium and large-scale applications	Battery sizing calculations, Utility Scale Battery Storage System, Batteries for Electric Vehicles	**TB1,TB3, RB3**
19	To familiar with the techno-commercial aspects of BESS design and its field scale implementation	Techno-commercial aspects of BESS design and applications.	**TB3, RB3**
20	To know about Fuel cells working principle and different types of fuel cells	Fuel Cells: Principle - working thermodynamics, Comparison on battery Vs fuel cell, Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, microbial fuel cells, relative merits and demerits.	**TB1,TB2**
21	To know about the hydrogen fuel cells	Hydrogen production for fuel cell feeding, fuel flexibility in fuel cells	**TB1,TB2**
22	To acquire knowledge about the fuel cell Applications	Polymer electrolyte membrane fuel cell, Portable and stationary application of fuel cells	**TB1,TB2**
23	To design electrical equivalent model of fuel cells	Electrical analysis of fuel cell with equivalent circuit and small fuel cell power plants	**TB1,TB2**
24	To integrate fuel cells in power systems	Fuel cell usage for domestic power systems	**TB1,TB2**
25	To learn about the large-scale power generation	large scale power generation	**TB1,TB2**
26	To analyze the fuel cells	Automobile, Space, economic and environmental analysis on usage of hydrogen and fuel cell	**TB1,TB2**
27	To explore the applications of fuel cells	Future trends in fuel cells, portable fuel cells	**TB1,TB2**
28	To learn about the Hydrogen Energy Storage	Hydrogen energy storage: Electrochemical-Electrolysis, photo electro chemical	**TB1,TB2**
29	To know about Photo-catalytic process	PM based electrolyser, Photo-electrolysis, Photo-catalytic	**TB1,TB2**

30	To learn about the Biological processes	Biological-Anaerobic digestion reactions-oxidation and reduction	**TB1,TB2**
31	To know about the Thermal Processes	Thermal-Steam reformation, thermos-chemical water splitting	**TB1,TB2**
32	To familiarize with the Hydrogen Storage	Hydrogen storage: Zeolites, metal hydride storage	**TB1,TB2**
33	To utilize the Hydrogen Storage in Renewables	Hydrogen as a storage medium for renewable energy systems.	**TB1,TB2**
34	To learn about the Super-capacitors	Super-capacitor storage, working principle	**TB1,TB2**
35	To plot its electrical characteristics	Electrical characteristics, Charging-discharging,	**TB1,TB2**
36	To know the practical utilization of Super-Capacitors	Super-capacitor Interfacing, Applications.	**TB1,TB2**
37	To know the basics of Thermal Storage	Introduction to Thermal Storage, Heat and cold energy storage	**TB1,TB2**
38	To learn about the different Thermal Storage Techniques	Heat and cold energy storage, Different storage techniques: sensible, latent, thermochemical storage	**TB1,TB2,RB 1**
39	To learn about the Phase Changing Materials (PCM)	Different materials and selection criteria, Phase Change Materials (PCMs) based Thermal Energy Storage	**TB1,TB2**
40	To enhance the understanding on Thermal Storage	Thermochemical Heat Storage Using Salt Hydrates, Cold Thermal Storage and Energy transport using Ice Slurry, their applications	**TB1,TB2**
41	To learn about the Compressed Air Energy Storage (CAES)	Compressed Air Energy Storage (CAES), Flywheel Energy storage, Applications	**TB1,TB2, RB1**
42	To know about the Pumped Hydro Energy Storage (PHES)	Pumped Hydro Energy Storage (PHES), Applications	**TB1,TB2, RB1**

Evaluation Scheme:

Component	Duration	Weightage (%)	Marks	Date & Time	Nature of Component

Quiz (Best 'one' out of 'two')	-	15%	30	To be announced	Closed Book
Mid-Semester examination	90 Minutes	30%	60	15/03 - 11.00 - 12.30PM	Closed Book
Group Project	-	20%	40	To be announced	Open Book
Comprehensive Examination	180 Minutes	35%	70	16/05 AN	Closed Book

Chamber Consultation Hour: To be announced at the beginning of the class

Notices: All the official notices related to this course will be uploaded on CMS

Make-up Policy: There will be make-up for the Mid-semester examination and Comprehensive examination subject to prior approval taken from the IC. No make-up is allowed for Quiz examination.

Academic Honesty and Integrity Policy: Academic honesty and integrity should be maintained by all the students throughout the semester and any type academic dishonesty is not acceptable.

Ankur Bhattacharjee

INSTRUCTOR-IN-CHARGE