DIPLOMA IN ENERGY STORAGE AND BATTERY MANAGEMENT SYSTEM

Syllabus

Program Code: BU-DL-ESBMS

2025 – 2026 Onwards

BHARATHIAR UNIVERSITY

(A State University, Accredited with "A++" Grade by NAAC

Ranked 46th among Indian Universities by MoE-NIRF

Coimbatore - 641 046, Tamil Nadu, India

BHARATHIAR UNIVERSITY :: COIMBATORE 641046

CENTRE FOR DISTANCE AND ONLINE EDUCATION (CDOE)

TITLE OF THE PROGRAM

DIPLOMA IN ENERGY STORAGE AND BATTERY MANAGEMENT SYSTEM

VISION

To become a leading diploma program that develops skilled, industry-ready professionals in energy storage and battery management systems, contributing to sustainable energy solutions, electric mobility, and smart power infrastructure.

MISSION

- To provide strong foundational and applied knowledge in energy storage technologies, battery chemistry, and battery management systems.
- To train students in practical skills related to battery assembly, testing, diagnostics, safety, and lifecycle management through hands-on laboratories and simulations.
- To align the curriculum with emerging industry trends such as electric vehicles, renewable energy integration, and smart grids.
- To promote sustainable practices, safety awareness, and environmental responsibility in energy storage applications.
- To enhance employability, entrepreneurship, and lifelong learning by fostering problem-solving, teamwork, and ethical professional practices.

DURATION

- **Minimum Duration**: One year
- **Maximum Duration:** Two years (with provision for Re-registration if required)

CREDIT DISTRIBUTION

- **Total Credits**: 40 credits (as per UGC credit framework)

ELIGIBILITY

- Candidates must have completed Higher Secondary (10+2) or equivalent examination with Chemistry as one of the subjects.

MEDIUM OF INSTRUCTION

- Medium of Instruction is English.

MODE OF LEARNING

- Open and Distance Learning (ODL)
- The programme shall be conducted through remote learning using a blend of print and digital learning materials, supplemented by Personal Contact Program (PCP) sessions to facilitate learner interaction and academic support

FEES STRUCTURE

- Fee structure as approved by the Centre for Distance and Online Education, Bharathiar University, Coimbatore.

ATTENDANCE

Particulars	Requirement for Diploma Programme
Number of Personal Contact Programs (PCPs)	20 PCPs
Duration of Each PCP	6 hours per PCP
Total Contact Hours	12 hours per course (120 hours)
Total study hours of learners	1200 hours
Mandatory Participation	75% in each course

REQUIREMENT TO APPEAR FOR THE EXAMINATIONS

A candidate enrolled in the programme shall be required to maintain the minimum prescribed attendance in both theory and practical classes, pay the prescribed examination fees, and satisfy all other conditions as stipulated by the University from time to time in order to be eligible to appear for the examinations.

CONDITIONS TO APPEAR FOR THE EXAMINATIONS

- **First Appearance:** Learners appearing for the examination for the first time shall register for all the prescribed courses of that semester by remitting the requisite examination fee.
- **Examination Centre:** Learners must specify their preferred examination centre in the examination application form. Once selected, the examination centre cannot be changed under any circumstances.
- **E-Hall Ticket:** Learners shall download their E-Hall Tickets from the University website and obtain the signature of the Chief Superintendent of the opted examination centre upon submission of their valid identity card. This process must be completed during the three working days preceding the commencement of the examinations.

EVALUATION PATTERN

A. Distribution of Marks in Continuous Internal Assessments (CIA): 25% weightage

The following procedure shall be followed for awarding internal marks for theory courses.

- Continuous Internal Assessment (CIA) Test - 10 marks
- Assignment - 5 marks
- Seminar - 5 marks
- Participation - 5 marks

Total - 25 marks

1. **CIA Test and question pattern**:

Two Continuous Internal Assessments (CIA-I & CIA II) must be conducted. Better of the TWO (the best and favorable one) will be counted for Test Marks (10 Marks)

- Section A – Objective Question 5*1 = 5 marks
- Section B – Short Essay (2 out of 3) 2*5 = 10 marks
- Section C – Essay Type (Either or type) 1*10 =10 marks

2. **Assignments – I and II**. Better of the TWO (the best one) will be counted for Assignment Marks (5 Marks)
3. **Seminar** will be conducted for 5 Marks.
4. **Participation** (which includes attendance) – 5 Marks

B. Project/Dissertation/Internship (4 Credits) – At the end of Second Semester

- Major project / Internship (100 marks)

  Internal – 50 Marks & External – 50 Marks

C. End-Semester Examination (ESE): 75% weightage

Mode and Duration of Examinations

1. Mode of Examination: All examinations shall be conducted offline at designated physical locations such as the University campus or approved Learner Support Centres (LSCs), under the supervision of duly appointed invigilators and as per the fixed examination schedule notified by the University.
2. Duration: Each examination shall be of three (3) hours' duration, covering both theoretical concepts and their practical applications.

Distribution of Marks in the End-Semester Examination - Question Paper Pattern:

Section	Type of question	No. of questions	Marks	Total
A	Objective Questions	10 (Compulsory)	1	10
B	Short Essay (300 words each)	3 out of 5	5	15
C	Essay Type (1000 words each)	5 Questions (Either or Type)	10	50
Total				**75**

D. Passing Criteria:

- A minimum of 40% aggregate marks, combining internal and external assessments, shall be required to pass each course.
- Minimum 40% passing marks in practical / project component
- Aggregate of 40% marks required for successful completion of the diploma programme.

E. Grading System: (As per 10-point UGC Credit Framework)

- The following table gives the marks, grade points, letter, grades and classification to Indicate the performance of the candidate.

For the entire programme:

- CGPA = Sum of the multiplication of grade points by the credits of the entire programme / Sum of the credits of the courses for the entire programme.

Cumulative Grade Point Average (CGPA) = $\sum n \sum i C_{ni} G_{ni} / \sum n \sum I C_{ni}$

RANGE	CGPA	GRADE	CLASSIFICATION OF RESULT
95-100	9.5-10.0	O+	**First Class- Exemplary***
90-94	9.0 and above but below 9.5	O	
85-89	8.5 and above but below 9.0	D++	**First Class with Distinction***
80-84	8.0 and above but below 8.5	D+	
75-79	7.5 and above but below 8.0	D	
70-74	7.0 and above but below 7.5	A++	**First Class**
65-69	6.5 and above but below 7.0	A+	
60-64	6.0 and above but below 6.5	A	
55-59	5.5 and above but below 6.0	B+	**Second Class**
50-54	5.0 and above but below 5.5	B	
45-49	4.5 and above but below 5.0	C+	**Third Class**
40-44	4.0 and above but below 4.5	C	
0-39	0.0 and above but below 4.0	U	**Re-appear**

a. A candidate who has passed all the courses in the first appearance within the prescribed duration of the diploma programmes and secured a CGPA of 9 to 10 and equivalent grades “O” or “O+” in Core and Practical/Project courses shall be placed in the category of “**First Class – Exemplary**”.

b. A candidate who has passed all the courses in the first appearance within the prescribed duration of the Diploma programmes and secured a CGPA of 7.5 to 9 and equivalent grades “D” or “D+” or “D++” in Core and Practical/Project courses shall be placed in the category of “**First Class with Distinction**”.

c. A candidate who has passed all the courses of the Diploma programmes and secured a CGPA of 6 to 7.4 and equivalent grades “A” or “A+” or “A++” in Core and Practical/Project courses shall be declared to have passed in “**First Class**”.

d. A candidate who has passed all the courses examination of the Diploma programmes and secured a CGPA of 5.0 to 5.9 and equivalent grades “B” or “B+” in Core and Practical/Project courses shall be declared to have passed in “**Second Class**”.

e. A candidate who has passed all the courses examination of the Diploma programmes and secured a CGPA of 4.0 to 4.9 and equivalent grades “C” or “C+” in Core and Practical/Project courses shall be declared to have passed in **“Third Class”.**

BHARATHIAR UNIVERSITY :: COIMBATORE -641046

CENTRE FOR DISTANCE AND ONLINE EDUCATION (CDOE)

DIPLOMA IN ENERGY STORAGE AND BATTERY MANAGEMENT SYSTEM

(For the students admitted during the academic year 2025 – 26 onwards

Course Code	Title of the Course	Credits	Hours		Maximum Marks		
			Theory	Practical	CIA	ESE	Total
			FIRST SEMESTER				
25 ESBMS 101	Fundamentals of Energy Storage Systems	4	12	--	25	75	100
25 ESBMS 102	Battery Chemistries and Materials	4	12	--	25	75	100
25 ESBMS 103	Battery Cell Design and Assembly	4	12	--	25	75	100
25 ESBMS 104	Battery Management Systems (BMS)	4	12	--	25	75	100
25 ESBMS 105	Practical I: AI-Based Battery Simulation Lab	2	--	12	20	30	50
	Total	**18**	**48**	**12**	**120**	**330**	**450**
			SECOND SEMESTER				
25 ESBMS 201	Battery Testing, Characterization, and Safety Standards	4	12	--	25	75	100
25 ESBMS 202	Energy Storage Integration and Grid Management	4	12	--	25	75	100
25 ESBMS 203	Thermal Management, Safety, and Recycling	4	12	--	25	75	100
25 ESBMS 204	AI and Digital Technologies in Energy Management	4	12	--	25	75	100
25 ESBMS 205	Practical II: Smart Energy and EV Charging Analytics Lab	2	--	12	20	30	50
25 ESBMS 206	Project Work on Energy Storage and Battery Management Systems	4	--	--	50	50	100
		22	**48**	**12**	**170**	**380**	**550**
	Grand Total	**40**	**96**	**24**	**290**	**710**	**1000**

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)	
After successful completion of the Diploma in Energy Storage and Battery Management System, the learners will be able to:	
PEO 1	Graduates will apply basic principles of energy storage and battery systems in real-world applications.
PEO 2	Graduates will support battery testing, Battery Management System (BMS) operation, and EV charging infrastructure.
PEO 3	Graduates will use digital tools and AI-assisted simulations for analysis and diagnostics.
PEO 4	Graduates will follow safety, sustainability, and professional practices in energy systems.
PEO 5	Graduates will pursue employment, skill upgradation, or higher education in energy-related fields.

PROGRAM SPECIFIC OUTCOMES (PSOs)	
After successful completion of the Diploma in Energy Storage and Battery Management System, the learners will be able to:	
PSO 1	Perform basic battery testing and performance evaluation using virtual tools.
PSO 2	Assist in BMS operation, monitoring, and fault identification.
PSO 3	Support EV charging station operation and energy storage integration.
PSO 4	Use AI-assisted platforms for battery simulation and diagnostics.
PSO 5	Contribute to energy storage projects in EV and renewable sectors.

PROGRAM OUTCOMES (POs)	
Upon successful completion of the Diploma in Energy Storage and Battery Management System, learners will be able to:	
PO1	Apply fundamental concepts of electrochemistry, electrical engineering, and energy storage systems to solve simple technical problems related to batteries and energy systems.
PO2	Identify and analyze common issues in battery performance, charging–discharging behaviour, thermal effects, and system faults using basic analytical tools.
PO3	Assemble, test, operate, and maintain different types of batteries and battery management systems using standard laboratory practices and simulation tools.
PO4	Utilize virtual laboratories, AI-based simulation, testing software, and diagnostic instruments for monitoring, analysis, and performance evaluation of energy storage systems.
PO5	Follow safety procedures, industry standards, and regulatory guidelines related to battery handling, electrical systems, environmental protection, and workplace safety.
PO6	Understand the environmental impact of energy storage technologies and apply principles of recycling, waste management, and sustainable energy practices.
PO7	Perform routine maintenance, fault identification, and corrective actions for batteries, chargers, and energy storage systems in industrial and field settings.
PO8	Demonstrate basic knowledge of service setup, small-scale battery business operations, maintenance services, and entrepreneurship opportunities.
PO9	Demonstrate ethical behaviour, responsibility, and discipline while working in laboratories, industries, and field environments.
PO10	Complete assigned projects and practical tasks independently and recognize the need for continuous skill development and lifelong learning in emerging energy storage technologies.

Course Code	25 ESBMS 101	**TITLE OF THE COURSE**	**Credits**	**PCP Hours**	**Study Hours of Learner**
Core Paper		FUNDAMENTALS OF ENERGY STORAGE SYSTEMS	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

The main objectives of this course are:

1. To introduce the fundamental concepts, need, and classification of energy storage systems in modern power networks.
2. To understand key performance parameters and their influence on the efficiency, reliability, and lifespan of energy storage systems.
3. To provide an overview of major energy storage technologies and their advantages, limitations, and selection criteria.
4. To familiarize learners with the components, architecture, and functional block diagram of energy storage systems.
5. To explain practical applications of energy storage in renewable integration, electric vehicles, and grid support services.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Explain the role and importance of energy storage in modern power systems and renewable energy integration.	**K2**
CO2	Classify different types of energy storage systems based on operating principles and application requirements.	**K2**
CO3	Analyze key performance parameters such as energy density, power density, efficiency, and cycle life.	**K4**
CO4	Compare various energy storage technologies and select suitable options for specific applications.	**K5**
CO5	Describe the components, balance of system, and overall architecture of an energy storage system.	**K1, K2**
CO6	Apply knowledge of energy storage systems to real-world applications such as peak shaving, load leveling, electric vehicles, and backup power systems.	**K3**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** – Create

BLOCK I: ENERGY STORAGE BASICS

Definition, need, and role of energy storage in modern power systems for reliability and renewable integration. Classification of energy storage systems as electrical, electrochemical, mechanical, and thermal. Comparison of short-term and long-term energy storage applications based on response time and capacity.

BLOCK II: PERFORMANCE PARAMETERS

Energy density, power density, efficiency, and cycle life concepts in energy storage systems – Charge-discharge characteristics, depth of discharge, and their impact on performance and lifespan – Round-trip efficiency and key factors influencing overall system reliability.

BLOCK III: STORAGE TECHNOLOGIES OVERVIEW

Batteries, supercapacitors, flywheels, and pumped hydro energy storage systems -Advantages and limitations of different energy storage technologies - Selection criteria for storage technologies based on application requirements.

BLOCK IV: ENERGY STORAGE SYSTEM COMPONENTS

Cells, modules, packs, power electronics, and enclosures in energy storage systems - Balance of system components including auxiliaries and support subsystems - Functional block diagram and overall architecture of an energy storage system.

BLOCK V: APPLICATIONS OF ENERGY STORAGE

Energy storage applications in renewable energy systems - Use of energy storage in electric vehicles and backup power systems - Role of energy storage in peak shaving and load leveling operations.

Textbooks (Primary Sources)

1. Andújar, J. M., Segura, F., & Durán, E., *Energy Storage Systems: Fundamentals, Classification and Applications*, Springer International Publishing, 2023.
2. Burheim, O. S., *Engineering Energy Storage*, Academic Press (Elsevier), 2017.
3. Dunn, B., Kamath, H., & Tarascon, J. M., *Electrical Energy Storage for the Grid: A Battery of Choices*, Science / AAAS, 2011.
4. Diwekar, U. M., *Introduction to Applied Optimization for Energy Systems*, Springer, 2018.
5. Dinçer, I., & Rosen, M. A., *Thermal Energy Storage: Systems and Applications*, 2nd Edition, Wiley, 2021.

Reference Books

1. Luo, X., Wang, J., Dooner, M., & Clarke, J., *Overview of Current Development in Electrical Energy Storage Technologies and the Application Potential in Power System Operation*, Applied Energy, Elsevier, 2015.
2. Olabi, A. G. (Ed.), *Renewable Energy Systems: Energy Storage Technologies*, Elsevier, 2022.
3. Newman, J., & Thomas-Alyea, K. E., *Electrochemical Systems*, 3rd Edition, Wiley-Interscience, 2004.
4. Bard, A. J., & Faulkner, L. R., *Electrochemical Methods: Fundamentals and Applications*, 2nd Edition, Wiley, 2001.
5. Eyer, J., & Corey, G., *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*, Sandia National Laboratories Report, 2010.

Course Designed By
Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.
Web Link 1. https://cldp.doc.gov/sites/default/files/2022-12/Understanding%20Energy%20Storage%20Book%20PDF-6.pdf?utm_source 2. https://ocw.mit.edu/courses/2-60j-fundamentals-of-advanced-energy-conversion-spring-2020/resources/mit2_60s20_lec11/?utm_source 3. https://onlinecourses.nptel.ac.in/noc21_mm34/preview?utm_source

MAPPING WITH PROGRAMME OUTCOMES

FUNDAMENTALS OF ENERGY STORAGE SYSTEMS

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	L	M	S	L	L	M	S
CO2	S	M	L	M	L	M	L	L	L	M
CO3	S	S	M	M	L	M	M	L	L	M
CO4	S	S	M	M	L	M	M	L	L	M
CO5	M	M	S	S	S	M	L	L	L	M
CO6	S	S	S	S	M	S	S	M	M	S

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 102	**TITLE OF THE COURSE**	**Credits**	**PCP Hours**	**Study Hours of Learner**
Core Paper		BATTERY CHEMISTRIES AND MATERIALS	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

By the end of this course, students will be able to:

1. To introduce fundamental concepts of electrochemical principles and battery chemistry.
2. To understand the construction, working, and performance of conventional battery systems.
3. To study lithium-ion battery chemistries and their application-specific selection.
4. To expose learners to advanced and emerging battery materials and technologies.
5. To analyze material degradation mechanisms and strategies for improving battery life and safety.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Explain basic electrochemical reactions and the role of battery components.	**K2**
CO2	Describe the construction and operating principles of lead-acid and nickel-based batteries.	**K2**
CO3	Compare different lithium-ion battery chemistries based on performance and safety parameters.	**K4**
CO4	Identify suitable battery chemistries for specific energy storage applications.	**K3**
CO5	Analyze material degradation, aging, and thermal effects in battery systems.	**K4**
CO6	Suggest methods to improve battery stability, lifespan, and operational safety.	**K5**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

Block I: Fundamentals of Battery Chemistry

Covers basic electrochemical reactions governing battery operation. Explains the functions of anode, cathode, electrolyte, and separator. Introduces the working principles of rechargeable batteries.

Block II: Lead-Acid and Nickel-Based Batteries

Focuses on construction and chemical reactions of lead-acid batteries. Discusses nickel-cadmium and nickel-metal hydride batteries. Highlights performance characteristics and common applications.

Block III: Lithium-Ion Battery Chemistries

Introduces major Li-ion chemistries such as LFP, NMC, NCA, and LCO. Compares voltage, energy density, safety, and lifespan. Emphasizes chemistry selection for specific applications.

Block IV: Advanced and Emerging Materials

Explores next-generation materials including solid-state electrolytes and silicon anodes. Introduces sodium-ion and zinc-based batteries. Discusses challenges related to materials, cost, and scalability.

Block V: Material Degradation and Stability

Examines aging and degradation mechanisms in battery materials. Analyzes the impact of temperature and charge–discharge cycling. Presents strategies to enhance stability and battery life.

Textbooks (Primary Sources)

1. Linden, D., & Reddy, T. B., Handbook of Batteries, 4th ed., McGraw-Hill Education, New York, 2011.
2. Xu, K., Nonaqueous Liquid Electrolytes for Lithium-Based Rechargeable Batteries, CRC Press, Boca Raton, 2004.
3. Pistoia, G., Battery Operated Devices and Systems: From Portable Electronics to Industrial Products, Elsevier, Amsterdam, 2009.
4. Scrosati, B., Abraham, K. M., van Schalkwijk, W., & Hassoun, J., Lithium Batteries: Advanced Technologies and Applications, Wiley, Hoboken, 2013.
5. Winter, M., & Brodd, R. J., What Are Batteries, Fuel Cells, and Supercapacitors?, Chemical Reviews, American Chemical Society, 2004.

Reference Books

1. Bard, A. J., & Faulkner, L. R., Electrochemical Methods: Fundamentals and Applications, 2nd ed., Wiley, New York, 2001.
2. Tarascon, J.-M., & Armand, M., Issues and Challenges Facing Rechargeable Lithium Batteries, Nature, 2001.
3. Goodenough, J. B., & Park, K.-S., The Li-Ion Rechargeable Battery: A Perspective, Journal of the American Chemical Society, 2013.
4. Zhang, S. S., A Review on Electrolyte Additives for Lithium-Ion Batteries, Journal of Power Sources, Elsevier, 2006.
5. Besenhard, J. O. (Ed.), Handbook of Battery Materials, Wiley-VCH, Weinheim, 1999.

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Chemistry_for_Changing_Times_%28Hill_and_McCreary%29/08%3A_Oxidation_and_Reduction/8.03%3A_Electrochemistry-_Cells_and_Batteries?utm_source
2. https://diyguru.org/term/battery-chemistry-overview/?utm_source
3. https://www.batterydesign.net/chemistry/?utm_source=chatgpt.com

MAPPING WITH PROGRAMME OUTCOMES

BATTERY CHEMISTRIES AND MATERIALS

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	L	L	L	L	L	L	L
CO2	S	M	M	L	M	L	M	L	L	L
CO3	S	S	L	M	M	L	L	L	L	L
CO4	M	S	M	M	M	L	M	M	L	L
CO5	M	S	L	M	M	L	M	L	L	L
CO6	M	M	M	M	S	S	M	M	S	S

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 103	**TITLE OF THE COURSE**	**Credits**	**PCP Hours**	**Study Hours of Learner**
Core Paper		BATTERY CELL DESIGN AND ASSEMBLY	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

By the end of this course, students will be able to:

1. To introduce different battery cell types, formats, and their applications.
2. To understand the design and function of key battery cell components.
3. To explain basic battery manufacturing and quality control processes.
4. To familiarize students with cell assembly, formation, and aging concepts.
5. To develop foundational knowledge of battery pack assembly and safety.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Identify different battery cell formats and select suitable applications.	**K1, K2**
CO2	Explain the function of electrodes, separators, and current collectors.	**K2**
CO3	Describe basic battery manufacturing and quality control processes.	**K1, K2**
CO4	Understand cell assembly, formation, and stabilization procedures.	**K2**
CO5	Apply basic concepts of cell matching and pack assembly.	**K3**
CO6	Demonstrate awareness of insulation, enclosure, and safety practices in battery systems.	**K2, K4**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

BLOCK I: BATTERY CELL TYPES AND FORMATS

Study of cylindrical, prismatic, and pouch cell formats and their construction- Comparison of structural features, energy density, and mechanical strength - Applications, advantages, and limitations of each cell format.

BLOCK II: CELL COMPONENT DESIGN

Basics of electrode materials, coating methods, and thickness optimization - Role of separators in ionic transport and cell safety - Design considerations for current collectors and casing materials.

BLOCK III: MANUFACTURING PROCESSES

Overview of slurry mixing, coating, calendaring, and drying processes - Cell stacking and winding techniques for different cell formats - Importance of cleanliness, process control, and quality assurance.

BLOCK IV: CELL ASSEMBLY AND FORMATION

Electrolyte filling, sealing techniques, and leak prevention methods - Initial charging, formation cycles, and SEI layer development - Aging, stabilization, and performance verification processes.

BLOCK V: PACK ASSEMBLY CONCEPTS

Cell matching, grading, and grouping for uniform performance - Mechanical assembly, electrical interconnections, and busbar design - Insulation methods, enclosure design, and basic safety considerations.

Textbooks (Primary Sources)

1. Rahn, C. D., & Wang, C.-Y. (2013). Battery systems engineering. Wiley.
2. Rosen, M. A., & Farsi, A. (2023). Battery technology: From fundamentals to thermal behavior and management. Elsevier.
3. Julien, C., Mauger, A., Vijh, A., & Zaghib, K. (2016). Lithium batteries: Science and technology. Springer.
4. Linden, D., & Reddy, T. B. (2010). Handbook of batteries (4th ed.). McGraw-Hill.
5. Garche, J., & Brandt, K. (2018). Electrochemical power sources: Fundamentals, systems, and applications. Elsevier.

Reference Books

1. Crompton, T. P. (2015). Battery reference book (3rd ed.). Elsevier.
2. Zoski, C. G. (Ed.). (2006). Handbook of electrochemistry. Elsevier.
3. Breitkopf, C., & Swider-Lyons, K. (Eds.). (2017). Springer handbook of electrochemical energy. Springer.
4. Bergveld, H. J., Kruijt, W. S., & Notten, P. H. L. (2002). Battery management systems: Design by modelling. Springer.
5. Wang, S., Fernandez, C., Fan, Y., Stroe, D.-I., & Chen, Z. (2021). Battery system modeling. Elsevier.

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://www.laserax.com/blog/ev-battery-cell-types?utm_source
2. https://www.leadintelligent.com/en/understanding-pouch-battery-cell/?utm_source
3. https://www.laserax.com/blog/ev-battery-manufacturing-process?utm_source
4. https://www.batterydesign.net/manufacture/cell-manufacturing/battery-cell-manufacturing-process/cell-assembly/?utm_source
5. https://inside.lgensol.com/en/2023/01/a-better-life-with-batteries-how-to-make-a-battery-step2-cell-assembly-pouch-battery-1/?utm_source

MAPPING WITH PROGRAMME OUTCOMES

BATTERY CELL DESIGN AND ASSEMBLY

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	L	S	L	L	L	M	L
CO2	S	M	L	L	L	L	L	M	L	L
CO3	M	M	S	L	S	M	L	L	L	L
CO4	M	M	S	M	L	L	L	L	L	L
CO5	M	M	S	M	M	L	L	L	L	L
CO6	L	L	M	L	S	M	M	M	L	M

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 104	TITLE OF THE COURSE	Credits	PCP Hours	Study Hours of Learner
Core Paper		BATTERY MANAGEMENT SYSTEMS (BMS)	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

By the end of this course, students will be able to:

1. Understand the purpose, architecture, and functions of Battery Management Systems (BMS).
2. Explain battery monitoring techniques including voltage, current, and temperature measurement.
3. Apply state estimation methods such as SOC, SOH, and SOP for battery analysis.
4. Analyze cell balancing, protection mechanisms, and fault handling strategies in BMS.
5. Evaluate BMS communication, control strategies, and integration with energy and vehicle systems.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Recall basic concepts, terminology, and functions of Battery Management Systems.	**K1**
CO2	Explain BMS architecture, monitoring principles, and measurement techniques.	**K2**
CO3	Apply SOC, SOH, and SOP estimation methods to simple battery systems.	**K3**
CO4	Analyze cell balancing techniques, protection schemes, and fault scenarios in BMS.	**K4**
CO5	Evaluate BMS performance, communication protocols, and system integration aspects.	**K5**
CO6	Design a basic conceptual BMS framework with monitoring, protection, and communication features.	**K6**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

BLOCK I: INTRODUCTION TO BATTERY MANAGEMENT SYSTEM (BMS)

Purpose and functions of a Battery Management System. Importance of battery monitoring, protection, and safety. Overview of BMS architecture and major functional blocks.

BLOCK II: BATTERY MONITORING TECHNIQUES

Voltage, current, and temperature measurement in battery systems. Sensor types and data acquisition methods used in BMS. Accuracy, calibration, and reliability considerations.

BLOCK III: STATE ESTIMATION METHODS

State of Charge (SOC) estimation techniques and approaches. State of Health (SOH) and State of Power (SOP) concepts and evaluation. Challenges in real-time state estimation.

BLOCK IV: CELL BALANCING AND PROTECTION

Passive and active cell balancing methods. Over-voltage, under-voltage, over-current, and short-circuit protection mechanisms. Fault detection and response strategies.

BLOCK V: BMS COMMUNICATION AND CONTROL

Communication protocols used in BMS. Integration of BMS with vehicle and energy storage systems. Data logging, diagnostics, and control functions.

Textbooks (Primary Sources)

1. Plett, G. L., *Battery Management Systems, Volume I: Battery Modeling*, Artech House, Boston, 2015.
2. Plett, G. L., *Battery Management Systems, Volume II: Equivalent-Circuit Methods*, Artech House, Boston, 2015.
3. Andrea, D., *Battery Management Systems for Large Lithium-Ion Battery Packs*, Artech House, Boston, 2010.
4. Xiong, R., *Battery Management Algorithm for Electric Vehicles*, Springer, Singapore, 2020.
5. Sun, X. (Ed.), *Advanced Battery Management Technologies for Electric Vehicles*, Wiley, Hoboken, 2021.

Reference Books

1. Bergveld, H. J., Kruijt, W. S., and Notten, P. H. L., *Battery Management Systems: Design by Modelling*, Springer, Dordrecht, 2002.
2. Pop, V., Bergveld, H. J., Danilov, D., Regtien, P. P. L., and Notten, P. H. L., *Battery Management Systems: Accurate State-of-Charge Indication for Battery-Powered Applications*, Springer, Dordrecht, 2008.
3. Dincer, I., Hamut, H. S., and Javani, N., *Thermal Management of Electric Vehicle Battery Systems*, Wiley, Chichester, 2017.
4. Weicker, P., *A Systems Approach to Lithium-Ion Battery Management*, Artech House, Boston, 2014.
5. Larminie, J., and Lowry, J., *Electric Vehicle Technology Explained*, Wiley, Chichester, 2012.

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://www.mathworks.com/discovery/battery-management-system.html?utm_source
2. https://www.researchgate.net/profile/Mohamed-Mourad-Lafifi/post/State-of-charge-estimation-of-lithium-ion-battery-MATLAB-simulink/attachment/5ab429654cde266d589336e0/AS%3A607104985489408%401521756516184/download/Battery%2BManagement%2BSystem%2BBMS%2Bfor%2BLithium%2BIon%2BBatterie.pdf?utm_source
3. https://www.scribd.com/document/755432987/Lecture-Notes-Battery-Management-System?utm_source
4. https://www.scribd.com/document/664202008/Battery-Management-System-for-Electric-Vehicles?utm_source
5. https://www.engineersgarage.com/understanding-battery-management-systems/?utm_source
6. https://allindiaev.com/battery-management-system-bms-architecture-a-technical-overview/?utm_source

MAPPING WITH PROGRAMME OUTCOMES

BATTERY MANAGEMENT SYSTEMS (BMS)

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	L	L	L	L	L	L	L	M	M
CO2	S	M	L	L	M	L	L	L	M	M
CO3	M	S	M	M	L	L	M	L	L	M
CO4	M	S	M	M	S	L	S	L	M	M
CO5	M	M	L	S	M	M	M	L	M	S
CO6	S	M	M	S	M	M	M	M	M	S

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

<table>
<tr><td>Course Code</td><td>25 ESBMS 105</td><td>TITLE OF THE COURSE</td><td>Credits</td><td>PCP Hours</td><td>Study Hours of Learner</td></tr>
<tr><td colspan="2">Practical Paper - I</td><td>AI-BASED BATTERY SIMULATION LAB</td><td>2</td><td>12</td><td>60</td></tr>
<tr><td colspan="2">Pre-requisite</td><td>Basic knowledge of chemistry, physics, and mathematics at the introductory level</td><td colspan="2">Syllabus Version</td><td>1</td></tr>
<tr><td colspan="6">Course Objectives</td></tr>
<tr><td colspan="6">The simulation lab course aims to:
1. To understand the fundamentals of batteries and AI-based simulation tools.
2. To study battery charging, discharging, and performance characteristics through virtual experiments.
3. To apply basic AI techniques for SOC and SOH estimation of batteries.
4. To analyze thermal behaviour and safety aspects of battery systems using simulations.
5. To introduce fault detection and diagnostics in battery systems using AI models.</td></tr>
<tr><td colspan="6">Expected Course Outcomes</td></tr>
<tr><td colspan="6">Upon successful completion of this course, the student will be able to:</td></tr>
<tr><td>CO1</td><td colspan="4">Explain basic battery principles and AI-based simulation concepts.</td><td>K1 & K2</td></tr>
<tr><td>CO2</td><td colspan="4">Simulate battery charge–discharge behaviour using virtual laboratory tools.</td><td>K2 & K3</td></tr>
<tr><td>CO3</td><td colspan="4">Apply AI methods to estimate battery State of Charge (SOC).</td><td>K3 & K4</td></tr>
<tr><td>CO4</td><td colspan="4">Evaluate battery State of Health (SOH) using simulated data.</td><td>K3, K4 & K5</td></tr>
<tr><td>CO5</td><td colspan="4">Analyze thermal effects and safety limits in battery operation.</td><td>K4 & K5</td></tr>
<tr><td>CO6</td><td colspan="4">Identify and classify common battery faults using AI-based techniques.</td><td>K3, K4, K5 & K6</td></tr>
<tr><td colspan="6">K1 - Remember; K2 - Understand; K3 - Apply; K4 - Analyze; K5 - Evaluate; K6 - Create</td></tr>
<tr><td colspan="6">AI-BASED BATTERY SIMULATION LAB – VIRTUAL EXPERIMENTS
1. State of Charge (SOC) Prediction Using AI
2. Battery Charging–Discharging Behaviour Analysis
3. State of Health (SOH) Estimation Using AI
4. Thermal Behaviour Prediction of Batteries
5. Fault Detection in Battery Systems Using AI</td></tr>
</table>

Textbooks (Primary Sources)

1. Torabi, Farschad & Ahmadi, Pouria. Simulation of Battery Systems: Fundamentals and Applications**.** Elsevier.
2. Bergveld, Henk Jan; Kruijt, Wanda S.; & Notten, Peter H. L. Battery Management Systems: Design by Modelling**.** Springer Dordrecht.
3. Hariharan, Krishnan S.; Tagade, Piyush; & Ramachandran, Sanoop. Mathematical Modeling of Lithium Batteries: From Electrochemical Models to State Estimator Algorithms**.** Springer.

Reference Books

1. Wang, Shunli; Fernandez, Carlos; Fan, Yongcun; Stroe, Daniel-Ioan; Chen, Zonghai; & others. Battery System Modeling**.** Elsevier.
2. Junqiu, Li. Modeling and Simulation of Lithium-ion Power Battery Thermal Management**.** Springer.

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://www.ijert.org/performance-improved-battery-modeling-for-ev-simulation?utm_
2. https://www.oalib.com/articles/6796795?utm_
3. https://www.sciencedirect.com/science/article/pii/S0360544223018558?utm_
4. https://www.mdpi.com/2227-7390/13/14/2247?utm_
https://pure.mpg.de/rest/items/item_3631031_1/component/file_3631032/content

MAPPING WITH PROGRAMME OUTCOMES

AI-BASED BATTERY SIMULATION LAB

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	S	L	M	L	L	M	M
CO2	M	S	M	S	L	L	L	L	M	M
CO3	M	S	M	S	L	L	L	L	M	M
CO4	M	S	M	S	L	L	L	L	M	M
CO5	M	S	L	S	S	M	M	L	M	M
CO6	M	S	M	S	S	L	S	L	M	M

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 201	**TITLE OF THE COURSE**	**Credits**	**PCP Hours**	**Study Hours of Learner**
Core Paper		BATTERY TESTING, CHARACTERIZATION, AND SAFETY STANDARDS	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

After completing this course, students will be able to:

1. To introduce the fundamentals and importance of battery testing, characterization, and validation.
2. To develop the ability to measure and analyze battery performance parameters such as capacity, energy, power, and efficiency.
3. To familiarize students with environmental, abuse, and safety testing procedures for batteries.
4. To provide knowledge of national and international battery safety standards and compliance requirements.
5. To train students in failure analysis techniques and professional test reporting practices.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Explain the purpose, methods, and significance of battery testing and validation processes.	**K1 & K2**
CO2	Perform standard performance characterization tests and interpret battery test data.	**K2, K3 & K4**
CO3	Conduct environmental and abuse tests and assess battery safety under extreme conditions.	**K2, K3 & K4**
CO4	Apply relevant battery safety standards and understand certification and compliance procedures.	**K1, K2 & K5**
CO5	Identify battery failure modes and perform basic root cause analysis.	**K3, K4 & K5**
CO6	Prepare structured test reports and technical documentation following standard practices.	**K3 & K6**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

Block I: Battery Testing Fundamentals

Purpose and importance of battery testing and validation - Electrical, thermal, and mechanical testing methods - Testing equipment, instrumentation, and standard test setups.

Block II: Performance Characterization

Capacity, energy, and power measurement techniques - Charge–discharge characteristics and profiling. Efficiency evaluation and cycle life testing.

Block III: Environmental and Abuse Testing

Temperature, vibration, and humidity testing procedures - Overcharge, short-circuit, and mechanical abuse tests - Safety assessment under extreme operating conditions.

Block IV: Battery Safety Standards

Overview of national and international battery safety standards - Certification, compliance, and regulatory requirements - Role of standards in product qualification and approval.

Block V: Failure Analysis and Reporting

Common battery failure modes and degradation mechanisms - Root cause analysis and diagnostic techniques - Preparation of test documentation and technical reports.

Textbooks (Primary Sources)

1. Battery Reference Book — Thomas P. J. Crompton
2. Handbook of Lithium-Ion Battery Pack Design — John T. Warner
3. Battery Technology Crash Course: A Concise Introduction — Slobodan Petrovic
4. Advanced Characterization Technologies for Secondary Batteries — Edited by Tinglu Song, Fan Xu & Chunli Li
5. Lithium-ion Batteries and Applications — Davide Andrea

Reference Books

1. Lithium-Ion Batteries: Fundamentals and Applications — Yuping Wu
2. Handbook of Battery Materials — Claus Daniel and Jürgen O. Besenhard
3. Rechargeable Batteries: Materials, Technologies and New Trends — Gianfranco Pistoia
4. Modern Batteries: An Introduction to Electrochemical Power Sources — C. A. Vincent and B. Scrosati
5. Battery Systems Engineering — Christopher D. Rahn and Chao-Yang Wang

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://www.batteryuniversity.com/articles/?utm_source
2. https://www.coursera.org/courses?query=battery&utm_
3. https://psr.edu.in/wp-content/uploads/2023/06/Battery-Technology.pdf?utm
4. https://haliatech.com/wp-content/uploads/2023/10/app-note-fundamentals-battery-module-pack-test.pdf?utm_

MAPPING WITH PROGRAMME OUTCOMES

BATTERY TESTING, CHARACTERIZATION, AND SAFETY STANDARDS

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	L	M	L	L	L	L	L
CO2	M	S	M	M	L	L	L	L	L	L
CO3	M	S	M	M	S	M	L	L	L	L
CO4	L	M	L	L	S	M	L	L	M	L
CO5	M	S	M	M	M	L	S	L	L	L
CO6	L	M	M	L	M	L	L	M	M	S

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESMBS 202	TITLE OF THE COURSE	Credits	PCP Hours	Study Hours of Learner
Core Paper		ENERGY STORAGE INTEGRATION AND GRID MANAGEMENT	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

After completing this course, students will be able to:

1. To understand the role and importance of energy storage systems in grid-connected and renewable energy applications.
2. To explain the principles of power electronic interfaces used for integrating energy storage with power grids.
3. To analyze the interaction between energy storage, generation sources, and electrical loads.
4. To study the application of energy storage for grid services such as frequency regulation, voltage support, and peak demand management.
5. To introduce the concepts of microgrids and smart grids with emphasis on energy storage integration.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Understand grid-connected energy storage fundamentals and roles in power systems.	**K2**
CO2	Differentiate centralized and decentralized energy storage systems.	**K2**
CO3	Apply power electronic interfaces for storage integration with grids.	**K3**
CO4	Analyze energy storage for renewable energy intermittency management.	**K4**
CO5	Evaluate grid services such as frequency regulation and peak demand control.	**K5**
CO6	Explain the role of energy storage in microgrids and smart grids.	**K2**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

Block I: Grid-Connected Energy Storage Basics

Role of energy storage in power grid operation and stability - Centralized and decentralized energy storage systems - Interaction of storage systems with generation sources and loads

Block II: Power Electronics for Integration

Inverters and converters used for energy storage integration - AC coupling and DC coupling methods - Grid synchronization techniques and control strategies

Block III: Renewable Energy Integration

Energy storage for solar and wind power smoothing - Management of intermittency and variability in renewables - Hybrid energy storage systems for renewable integration

Block IV: Grid Services and Applications

Frequency regulation and voltage support using storage - Peak demand management applications - Backup power and grid resilience enhancement

Block V: Microgrids and Smart Grids

Role of energy storage in microgrid operation - Islanding and reconnection strategies - Energy storage in smart grid infrastructure

Textbooks (Primary Sources)

1. Andújar Márquez, J. M., Segura Manzano, F., & Rey Luengo, J. (2023). Energy Storage Systems: Fundamentals, Classification and a Technical Comparative. Springer Cham.
2. Sterner, M., & Stadler, I. (2019). Handbook of Energy Storage: Demand, Technologies, Integration. Springer.
3. Dunlap, R. A. (2025). Renewable Energy Storage: Electrical, Magnetic, and Chemical Methods. Springer.
4. Suntio, T., & Messo, T. (Eds.). (2019). Power Electronics in Renewable Energy Systems. MDPI Books.
5. Micallef, A., & Xiao, Z. (Eds.). (2023). Microgrids and the Integration of Energy Storage Systems. MDPI Books.

Reference Books

1. Ertugrul, N. (2025). Reinventing the Power Grid: Renewable Energy, Storage, and Grid Modernization. CRC Press.
2. Moseley, P., & Garche, J. (2018). Electrochemical Energy Storage for Renewable Sources and Grid Balancing. Elsevier.
3. Du, P., & Lu, N. (2018). Energy Storage for Smart Grids. Elsevier.
4. Blinov, A. B., & Williamson, S. W. (Eds.). (2022). Power Electronics and Energy Management for Battery Storage Systems. MDPI Books.
5. Sahoo, U. (2021). Energy Storage. Wiley-VCH.

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://web.engr.oregonstate.edu/~webbky/ESE471_files/Section%201%20Grid%20Connected%20Energy%20Storage.pdf?utm_
2. https://mrcet.com/downloads/digital_notes/EEE/24082023/ENERGY%20STORAGE%20SYSTEMS%20DIGITAL%20NOTES.pdf?utm_

MAPPING WITH PROGRAMME OUTCOMES

ENERGY STORAGE INTEGRATION AND GRID MANAGEMENT

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	L	L	M	L	L	L	L
CO2	M	S	L	L	L	L	L	L	L	L
CO3	M	M	S	S	M	L	M	L	L	L
CO4	M	S	L	M	L	M	L	L	L	L
CO5	M	M	L	L	M	M	L	L	L	L
CO6	L	L	L	M	L	L	L	L	M	M

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 203	TITLE OF THE COURSE	Credits	PCP Hours	Study Hours of Learner
Core Paper		THERMAL MANAGEMENT, SAFETY, AND RECYCLING	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

After completing this course, students will be able to:

1. To understand thermal behavior and heat generation mechanisms in batteries.
2. To study battery thermal management systems and cooling techniques.
3. To analyze safety design principles and risk mitigation strategies in battery systems.
4. To learn battery aging, end-of-life criteria, and second-life applications.
5. To understand battery recycling technologies and environmental regulations.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Explain heat generation and thermal effects in batteries.	**K2**
CO2	Describe thermal runaway and safety risks in battery systems.	**K2**
CO3	Apply suitable thermal management techniques for batteries.	**K3**
CO4	Analyze safety-oriented battery system designs.	**K4**
CO5	Evaluate battery end-of-life and second-life options.	**K5**
CO6	Understand recycling methods and sustainability regulations.	**K2**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

BLOCK I: THERMAL BEHAVIOR OF BATTERIES

Study heat generation mechanisms during battery operation and temperature effects on performance and lifespan - Understand fundamentals of thermal runaway and thermal safety concerns in batteries - Analyze thermal characteristics of different battery chemistries and their impact on system reliability.

BLOCK II: BATTERY THERMAL MANAGEMENT SYSTEMS

Learn air, liquid, and phase-change cooling methods used in battery packs - Study design considerations, material selection, and system integration for thermal management - Understand monitoring, control, and regulation of battery temperature in real-time operation.

BLOCK III: SAFETY DESIGN AND RISK MITIGATION

Understand battery enclosure design, insulation techniques, and safety barriers - Study fire prevention, detection, and suppression methods for battery systems - Apply safety-oriented design principles to minimize thermal and electrical risks.

BLOCK IV: BATTERY END-OF-LIFE MANAGEMENT

Study battery aging, degradation mechanisms, and health assessment methods - Understand criteria for battery retirement and evaluation for second-life applications - Learn repurposing strategies for stationary energy storage systems.

BLOCK V: RECYCLING TECHNOLOGIES AND REGULATIONS

Study mechanical, chemical, and thermal battery recycling processes - Understand recovery techniques for valuable battery materials and resources - Learn environmental regulations, standards, and sustainability practices in battery recycling.

Textbooks (Primary Sources)

1. Pesaran, A. A., *Battery Thermal Management Systems*, SAE International, 2013.
2. Rao, Z., *Thermal Management of Lithium-Ion Batteries*, Springer, 2018.
3. Larminie, J., and Lowry, J., *Electric Vehicle Technology Explained*, Wiley, 2012.
4. Spotnitz, R., *Lithium-Ion Battery Safety and Abuse Tolerance*, Elsevier, 2016.
5. Linden, D., and Reddy, T. B., *Handbook of Batteries*, McGraw-Hill, 2011.

Reference Books

1. Scrosati, B., Garche, J., and Tillmetz, W., *Lithium-Ion Batteries: Advanced Materials and Technologies*, Wiley, 2015.
2. Bandhauer, T. M., Garimella, S., and Fuller, T. F., *A Critical Review of Thermal Issues in Lithium-Ion Batteries*, Journal of Power Sources, 2011.
3. Pistoia, G., *Battery Operated Devices and Systems*, Elsevier, 2009.
4. Gaines, L., *Lithium-Ion Battery Recycling Processes*, Sustainable Materials and Technologies, 2014.
5. European Commission, *Battery Recycling and Sustainability Regulations*, EU Publications, 2020.

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://in.mathworks.com/discovery/battery-thermal-management-system.html?utm
2. https://isieindia.com/courses/battery-thermal-management-and-safety/?utm
3. https://www.circunomics.com/blog/second-life-applications-for-ev-batteries?utm
4. https://www.epa.gov/hw/lithium-ion-battery-recycling?utm
5. https://docs.nrel.gov/docs/fy23osti/84520.pdf?utm
6. https://pubs.acs.org/doi/pdf/10.1021/acsenergylett.1c02602?ref=article_openPDF

MAPPING WITH PROGRAMME OUTCOMES

THERMAL MANAGEMENT, SAFETY, AND RECYCLING

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	L	L	L	L	L	L	L
CO2	M	S	L	L	S	L	L	L	M	L
CO3	L	M	S	S	L	L	M	L	L	L
CO4	L	S	M	M	S	L	M	L	L	L
CO5	L	L	L	L	L	S	M	M	L	L
CO6	L	L	L	L	M	S	L	L	M	M

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 204	TITLE OF THE COURSE	Credits	PCP Hours	Study Hours of Learner
Core Paper		AI AND DIGITAL TECHNOLOGIES IN ENERGY MANAGEMENT	4	12	120
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

After completing this course, students will be able to:

1. Apply digitalization and AI concepts to monitor, model, and optimize energy storage systems.
2. Understand data acquisition, digital twins, and AI-based battery analytics for performance evaluation.
3. Develop skills in predictive maintenance, fault detection, and remaining useful life estimation of batteries.
4. Implement AI-enabled energy management and smart grid integration strategies.
5. Analyze emerging digital solutions, cloud-based monitoring, and industry trends in energy storage.

Expected Course Outcomes

On the successful completion of the course, student will be able to

CO1	Explain the role of digital technologies and AI in modern energy storage systems.	**K2**
CO2	Develop data-driven models to predict battery behavior and performance.	**K3**
CO3	Apply AI techniques for predictive maintenance and fault detection in batteries.	**K3**
CO4	Analyze remaining useful life and degradation patterns using AI-based analytics.	**K4**
CO5	Design AI-enabled energy management strategies for demand forecasting and optimization.	**K6**
CO6	Evaluate emerging trends, digital solutions, and cloud-based platforms in energy storage.	**K5**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

BLOCK I: DIGITALIZATION IN ENERGY STORAGE

Study the role of digital technologies in energy storage systems and energy networks - Understand data acquisition, monitoring platforms, and digital twin concepts for batteries - Analyze the impact of digitalization on performance optimization, safety, and lifecycle management.

BLOCK II: AI BASICS FOR ENERGY APPLICATIONS

Study fundamental concepts of artificial intelligence and machine learning for energy systems - Understand data-driven modeling approaches for battery behavior using operational data - Analyze training, validation, and performance evaluation of AI models.

BLOCK III: AI-BASED BATTERY ANALYTICS

Study AI techniques for predictive maintenance of battery systems - Understand remaining useful life estimation methods for batteries - Analyze fault detection and anomaly identification using data analytics.

BLOCK IV: SMART ENERGY MANAGEMENT SYSTEMS

Study AI-enabled energy scheduling and optimization methods - Understand demand forecasting and intelligent load management techniques - Analyze integration of energy management systems with BMS and grid infrastructure.

BLOCK V: FUTURE TRENDS AND INDUSTRY USE CASES

Study AI applications in smart grids, EV fleets, and energy storage industries - Understand cloud-based battery monitoring and analytics platforms - Analyze emerging digital solutions and future trends in energy storage systems.

Textbooks (Primary Sources)

1. Larminie, J., & Lowry, J. (2012). *Electric Vehicle Technology Explained* (2nd ed.). John Wiley & Sons.
2. Plett, G. L. (2015). *Battery Management Systems, Volume I: Battery Modeling*. Artech House.
3. Plett, G. L. (2015). *Battery Management Systems, Volume II: Equivalent-Circuit Methods*. Artech House.
4. Bishop, C. M. (2006). *Pattern Recognition and Machine Learning*. Springer.
5. Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press.

Reference Books

1. Yang, Y., & Wang, C. (2021). *Artificial Intelligence in Energy and Renewable Energy Systems*. Academic Press.
2. Zio, E. (2016). *Prognostics and Health Management of Industrial Systems*. Springer.
3. Kroposki, B., et al. (2017). *Energy Storage Integration: Applications, Economics, and Future Trends*. IEEE Press / Wiley.
4. Nielsen, M. A. (2015). *Neural Networks and Deep Learning*. Determination Press.
5. Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). *Overview of Current Development in Electrical Energy Storage Technologies and Applications*. Elsevier.

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://www.mdpi.com/2313-0105/11/8/298?utm_
2. https://arxiv.org/abs/2509.02366?utm_
3. https://www.sciencedirect.com/science/article/pii/S1364032125013358?utm_
4. https://www.mdpi.com/1996-1073/18/17/4718?utm
5. https://www.energy.gov/sites/default/files/2024-05/AI%20for%20Energy%20Storage%20Challenges%20and%20Opportunities%20-%20Mary%20Ann%20Piette.pdf?utm

MAPPING WITH PROGRAMME OUTCOMES

AI AND DIGITAL TECHNOLOGIES IN ENERGY MANAGEMENT

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	M	M	L	S	L	L	L	L	L	M
CO2	M	S	L	S	L	L	L	L	L	M
CO3	L	S	M	S	L	L	M	L	L	M
CO4	L	S	L	S	L	M	L	L	L	M
CO5	M	M	L	S	L	M	L	M	L	M
CO6	L	M	L	M	M	S	L	M	M	M

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 205	TITLE OF THE COURSE	Credits	PCP Hours	Study Hours of Learner
Practical Paper - II		SMART ENERGY AND EV CHARGING ANALYTICS LAB	2	12	60
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

Course Objectives

The objectives are broad intentions that describe what the course aims to achieve.

1. Understand fundamentals of smart energy systems and EV charging analytics using AI tools
2. Apply ChatGPT-based virtual lab methods to simulate EV charging scenarios
3. Analyze EV charging load patterns and grid interaction using AI-generated data
4. Evaluate smart charging strategies for energy efficiency and cost optimization
5. Create AI-assisted analytical models for smart energy and EV charging applications

Expected Course Outcomes

Upon successful completion of this course, the student will be able to:

CO1	Recall key concepts of smart energy systems and EV charging infrastructure	**K1**
CO2	Explain EV charging analytics and smart charging principles using AI tools	**K2**
CO3	Apply ChatGPT to simulate and study EV charging load profiles and scenarios	**K3**
CO4	Analyze the impact of EV charging on energy demand and grid performance	**K4**
CO5	Evaluate different smart charging and energy management strategies	**K5**
CO6	Design AI-based virtual experiments for smart energy and EV charging analytics	**K6**

K1 - Remember; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

EXPERIMENTS

1. EV charging load profile generation and analysis using AI-based simulated datasets
2. Smart EV charging schedule optimization through prompt-based analytical modeling
3. Distribution grid impact assessment of EV charging using AI-driven scenario analysis
4. Renewable-assisted EV charging station energy management using AI analytics
5. EV battery state-of-charge prediction and trend analysis using ChatGPT-based models

Textbooks (Primary Sources)

1. *Electric Vehicles in Energy Systems: Modelling, Integration, Analysis, and Optimization* – Ali Ahmadian, Behnam Mohammadi-Ivatloo, Ali Elkamel
2. *Artificial Intelligence for Integrated Smart Energy Systems in Electric Vehicles* – Surender Reddy Salkuti (Ed.)
3. *Optimization of Electric-Vehicle Charging: Scheduling and Planning Problems* – Giulio Ferro et al.
4. *Smart Grids for Renewable Energy Systems, Electric Vehicles and Energy Storage Systems* – Rajkumar Viral et al.
5. *Electric Vehicle Integration via Smart Charging: Technology, Standards, Implementation, and Applications* – Vahid Vahidinasab & Behnam Mohammadi-Ivatloo

Reference Books

1. *Development of Electric Vehicles in Smart Grid Concepts* – Supriya Jaiswal et al.
2. *Electric Vehicle Integration in a Smart Microgrid Environment* – Mohammad Saad Alam & Mahesh Krishnamurthy
3. *Plug In Electric Vehicles in Smart Grids: Integration Techniques* – Sumedha Rajakaruna et al.
4. *Plug In Electric Vehicles in Smart Grids: Energy Management* – Sumedha Rajakaruna et al.
5. *Modeling Power Electronics and Interfacing Energy Conversion Systems* – Farret & Méndez (Simões)

Course Designed By

Dr. P. MANIVASAKAN, Assistant Professor of Chemistry, Centre for Distance and Online Education (CDOE), Bhrathiar University, Coimbatore – 46.

Web Link

1. https://intelliarts.com/blog/data-analytics-in-electric-vehicle-energy-management/?utm_
2. https://energy-ready.org/wp-content/uploads/2025/01/Charging-Smart-Program-Guide-v3.1.pdf?utm_
3. file:///C:/Users/welcome/Downloads/ACN-Sim_An_Open-Source_Simulator_for_Data-Driven_Electric_Vehicle_Charging_Research.pdf

CO – PO MAPPING TABLE

SMART ENERGY AND EV CHARGING ANALYTICS LAB

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	L	M	L	L	L	L	M	M
CO2	M	S	L	S	L	L	L	L	M	M
CO3	M	M	L	S	L	L	L	L	L	S
CO4	M	S	L	S	L	M	L	L	L	M
CO5	M	M	L	S	M	S	L	L	M	M
CO6	M	M	L	S	L	M	L	M	M	S

Mapping convention: **S = Strong**, **M = Moderate**, **L = Low**

Course Code	25 ESBMS 206	PROJECT WORK	Credits	PCP Hours	Study Hours of Learner
Project Area		ENERGY STORAGE AND BATTERY MANAGEMENT SYSTEMS	4	--	--
Pre-requisite		Basic knowledge of chemistry, physics, and mathematics at the introductory level	**Syllabus Version**		1

1. SCHEME FOR EXECUTION OF THE PROJECT

Phase I – Project Identification & Planning

- Selection of project title related to Energy Storage / BMS
- Identification of problem statement and application area
- Literature survey (journals, textbooks, standards, reports)
- Definition of objectives, scope, and expected outcomes

Deliverables:

- Project proposal
- Problem statement
- Objectives and scope

Phase II – System Design & Methodology

- Study of energy storage technologies (Li-ion, lead-acid, supercapacitors, etc.)
- Selection of battery type and BMS architecture
- Design of block diagram and system flow
- Selection of tools (MATLAB/Simulink, Python, Proteus, hardware kits if any)
- Methodology formulation (simulation / analytical / experimental)

Deliverables:

- System block diagram
- Design specifications
- Methodology flowchart

Phase III – Implementation / Simulation / Experimentation

- Development of battery model
- Implementation of BMS functions:
  - State of Charge (SoC)
  - State of Health (SoH)
  - Voltage, current, temperature monitoring
  - Protection logic
- Simulation or hardware testing
- Data collection and result generation

Deliverables:

- Simulation results / experimental observations
- Screenshots / test results

Phase IV – Analysis & Validation

- Performance analysis of energy storage system
- Comparison with standard/expected values
- Identification of limitations and challenges
- Validation of results

Deliverables:

- Graphs, tables, analysis discussion

Phase V – Documentation & Presentation

- Preparation of final project report
- Preparation of PowerPoint presentation
- Project demonstration / viva voce

Deliverables:

- Final bound report
- Presentation slides

2. SCHEME OF EVALUATION (TOTAL: 100 MARKS)

S. No	Evaluation Component	Marks
1	Problem Identification & Objectives	10
2	Literature Survey & Background Study	10
3	System Design & Methodology	15
4	Implementation / Simulation / Experiment	20
5	Results, Analysis & Discussion	15
6	Innovation / Application Relevance	10
7	Project Report Quality	10
8	Presentation & Viva Voce	10
Total		**100**

3. PROJECT REPORT PATTERN (STANDARD FORMAT)

1. Cover Page
    - Title of the project
    - Student name(s), Register number(s)
    - Course / Department
    - Institution name
    - Academic year
2. Bonafide Certificate
3. Abstract : Brief summary of the project (problem, method, results)
4. Acknowledgement
5. Table of Contents
6. List of Figures
7. List of Tables
8. Chapter 1: Introduction
    - Overview of energy storage systems
    - Importance of Battery Management Systems
    - Motivation for the project
9. Chapter 2: Literature Review
    - Review of existing energy storage technologies
    - Review of BMS techniques
    - Research gaps
10. Chapter 3: System Description & Methodology
    - System block diagram
    - Description of components
    - Methodology adopted
11. Chapter 4: Implementation / Simulation / Experimental Setup
    - Software/hardware tools used
    - Model development
    - Test conditions
12. Chapter 5: Results and Analysis
    - Output results
    - Performance analysis
    - Graphs and tables
13. Chapter 6: Conclusion and Future Scope
    - Summary of work carried out
    - Key findings
    - Scope for future improvements
14. References
    - IEEE / standard reference format
15. Appendices (if any)