INSTITUTE	**FACULTY OF TECHNOLOGY**
PROGRAM	**MASTER OF TECHNOLOGY in ELECTRICAL ENGINEERING**
SEMESTER	**2**
COURSE TITLE	**BATTERY MANAGEMENT SYSTEMS**
COURSE CODE	**01EV1201**
COURSE CREDITS	**4**

Objective:

1 The objective of this course is to introduce learner to batteries, its parameters, modelling and charging requirements. The course will help learner to develop battery management algorithms for batteries

Course Outcomes: After completion of this course, student will be able to:

1 Interpret the role of battery management system
2 Identify the requirements of Battery Management System
3 Interpret the concept associated with battery charging / discharging process
4 Calculate the various parameters of battery and battery pack
5 Design the model of battery pack

Pre-requisite of course: Basics of Electrical Engineering (or equivalent subject), Circuit Network, Physics

Teaching and Examination Scheme

Theory Hours	Tutorial Hours	Practical Hours	ESE	IA	CSE	Viva	Term Work
3	0	2	50	30	20	25	25

Contents : Unit	Topics	Contact Hours
1	**Unit - I - Introduction:** Introduction - Naming Conventions, Li-Ion Cells,, Introduction - Li-Ion BMS's, Li-Ion Batteries, BMS options - Functionality. Technologies, BMS Options - Topology, BMS functions - Measurement, Managements, BMS Functions - Evalution, External Communications, Logging and Telemetry	6
2	**Unit - II - Battery Management System Requirement:** Battery Pack topology, BMS design requirements, Battery-pack sensing - voltage, temperature and current, High voltage contactor control, Isolation sensing, Thermal control, Protection, Communication via CAN bus, Log Book function, State of charge estimation, Enegy estimation, Power estimation, Diagnosis	10

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Contents : Unit	Topics	Contact Hours
3	**Unit - III - Battery State of Charge and State of Health Estimation, Cell Balancing** Battery state of charge estimation (SOC),, voltage-based methods to estimate SOC, Model-based state estimation, Battery Health Estimation, Lithium-ion aging: Negative electrode, Lithium ion aging: Positive electrode, Cell Balancing, Causes of imbalance, Circuits for balancing	10
4	**Unit - IV - Modelling and Simulation:** Equivalent-circuit models (ECMs),, Physics-based models (PBMs), Empirical modelling approach,, Physics-based modelling approach, Simulating an electric vehicle, Vehicle range calculations, Simulating constant power and voltage, Simulating battery packs,	6
5	**Unit - V - Design of battery BMS:** Design principles of battery BMS,, Effect of distance, load, and force on battery life and BMS,, energy balancing with multi-battery system	10
Total Hours		**42**

Suggested List of Experiments:

Contents : Unit	Topics	Contact Hours
1	**Experiment No. - 01** To model a lead-acid battery cell using the Simscape™	
2	**Experiment No. - 02** Observe the charging and discharging process, and plot graph of charging/load current, SOC, temperature, DOC, and terminal voltage.	
3	**Exxperiment No. - 03** To analyse the effect of temperature on the performance of a Lithium-Ion battery model	
4	**Experiment No. - 04** To simulate and plot the result of temperature, SOC, current, and terminal voltage for the HV Battery Charge/Discharge using realistic DC-link current profile, which originates from a dynamic driving cycle	
5	**Experiment No. - 05** To study Lithium Battery Cell - One RC-Branch Equivalent Circuit and it's simulation	
6	**Experiment No - 06** To simulate Ni-MH Battery Model with the DC machine and show the charging and discharging process using DC machine.	
7	**Experiment No. - 07** To simulate Lithium-Ion (LiFePO4) Battery and analyse the effect of DOD and discharge rate on battery ageing considering 1000 h simulation time	
Total Hours		

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Textbook :

1 Battery management systems, Volume I: Battery modeling., Plett, Gregory L., Artech House, 2015

2 Battery management systems, Volume II: Equivalent-circuit methods., Plett, Gregory L., Artech House,, 2015

3 Battery Management Systems -Design by Modelling, Bergveld, H.J., Kruijt, W.S., Notten, P.H.L, Philips Research Book Series, 2002

4 Battery Management Systems for Large Lithium-ion Battery Packs, Davide Andrea, Artech House, 2010

5 Battery management systems: Accurate state-of-charge indication for battery-powered applications., Pop, Valer, et al., Springer Science & Business Media,, 2008

6 Electrochemical Methods: Fundamentals and Applications. 2nd ed., Bard, Allen J., and Larry R. Faulkner., Wiley– VCH, Verlag, GmbH, 2000

7 Lithium ion Batteries Fundamental and Performance, Masataka Wakihara and Osamu Yamamoto, Wiley–VCH, Verlag GmbH, 1999

8 Advanced Batteries – Materials science aspects, Robert A.Huggins, Springer, 2009

References:

1 Understanding Batteries, Understanding Batteries, Dell, Ronald M Rand, David A J, Royal Society of Chemistry, 2001

Suggested Theory Distribution:

The suggested theory distribution as per Bloom's taxonomy is as follows. This distribution serves as guidelines for teachers and students to achieve effective teaching-learning process

Distribution of Theory for course delivery and evaluation					
Remember / Knowledge	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Higher order Thinking / Creative**
5.00	10.00	15.00	30.00	20.00	20.00

Instructional Method:

1 The course delivery method will depend upon the requirement of content and need of students. The teacher in addition to conventional teaching method by black board, may also use any of tools such as demonstration, role play, Quiz, brainstorming, MOOCs etc

2 The internal evaluation will be done on the basis of continuous evaluation of students in the laboratory and classroom.

3 Practical examination will be conducted at the end of semester for evaluation of performance of students in laboratory.

4 Students will use supplementary resources such as online videos, NPTEL videos, e-courses, Virtual Laboratory

Supplementary Resources:

1 https://www.coursera.org/learn/battery-management-systems

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Supplementary Resources:

2 https://www.coursera.org/specializations/algorithms-for-battery-management-systems

3 https://www.sciencedirect.com/science/article/abs/pii/S135943111835614X

4 https://iopscience.iop.org/article/10.1088/1757-899X/912/4/042005/pdf

5 https://www.researchgate.net/publication/329410156_Review_on_Battery_Thermal_Management_System_for_Electric_Vehicles

6 https://www.ansys.com/en-in/applications/battery/battery-management-systems

7 https://www.integrasources.com/blog/battery-management-systems-software-development/