ELECTRIC VEHICLE CHARGING SYSTEMS FOR EEE

Contents

Course Details

Course Code	L	T	P	C
SB8008	1	0	2	2

COURSE DESCRIPTION

The global market for electric vehicles (EVs) is growing continuously at a compounded annualized growth rate (CAGR) of 21.7 per cent. It is expected to grow from 8.1 million units to 39.21 million units by 2030. This exponential growth is being driven by various factors, including concerns for pollution. In this course, students will get exposed to Electric vehicle, Predict aspects of mobility in the future. Comprehend the basics of battery technology. covers developing equivalent circuit model for the battery pack for performing various studies like OCV and ECM in simulation aspect. It also covers fault estimation in battery packs during short circuit and overload. The control system should kick in to protect the battery pack with design constrains.

COURSE OBJECTIVE

- Students to get exposed to Electric vehicle & mobility dynamics & Battery Management Systems. Demonstrate Battery State-of-charge (Estimation) & Battery State-of ?Health (SOH) Estimation using lab exercises integrated in the platform as part of the tutorials. Design of various converter topologies which involves selection of components, switching pulses and switches using LTspice simulation tool, sensing of various battery parameters like SCO and SOH and developing EKF and SPKF using Octave Code.
- To Design 48v 36Ah LIFEPO4 battery pack for the dimension of 430mm(L) x 15mm(B) x 160mm(H) and develop the control circuit for sensing the individual array temperature with OV and UV protection with minimum harmonic content also calculate the SOC and SOH using Octave model

COURSE CURRICULUM

UNIT I - INTRODUCTION TO ELECTRIC VEHICLES & AUTOMATION (3T+6P)

Theory component:
-Future of Mobility ? [5 Videos, 3 Readings,2 Quizzes]
-Electrification : The Basic Technologies (Part 1) Electric Vehicles, batteries, EVs Made up of? [5 Videos, 2 Reading,2 Quizzes]
-Electrification : The Basic Technologies (Part 2) ?Charging & Charging Infrastructure, EV & the power systems, Industry Perspective on Applications of Electrification [7 Videos, 6 Readings, 2 Quizzes]
-Electrification Impacts ? [7 Videos, 2 Quizzes]
-Vehicle Automation ? The Basic Technologies ? [9 Videos, 1 Reading, 2 Quizzes]
-Automation ? The Impacts ? [6 Videos,1 Quiz]

UNIT II - EQUIVALENT CIRCUIT CELL MODEL SIMULATION (3T+6P)

Theory component:
-Defining an equivalent-circuit model of a Li-ion cell - [9 Videos, 14 Readings, 9 Quizzes & 1 Overall Quiz]
-Identifying parameters of static model - [6 Videos, 7 Readings, 6 Quizzes & 1 Overall Quiz]
-Identifying parameters of dynamic model- [9 Videos, 9 Readings, 7 Quizzes & 1 Overall Quiz]
-Simulating battery packs in different configurations - [6 Videos, 6 Readings, 6 Quizzes & 1 Overall Quiz]
-Co-simulating battery and electric-vehicle load - [7 Videos, 7 Readings, 5 Quizzes & 1 Overall Quiz]

Practical/Lab component:

1. Octave Code to determine static part of ECM ? Jupyter notebook used in conjunction
2. Identifying parameters of static model - Jupyter notebook used in conjunction
3. Octave Code to determine dynamic part of an ECM
4. Octave Code to simulate an ECM
5. Octave code to look up model parameter value
6. Octave code to compute OCV
7. ECM to simulate constant voltage
8. ECM to simulate constant power
9. Octave code to simulate PCM?s
10. Octave code to simulate SCM?s
11. Octave code to co-simulate EV and Battery
12. Tune a Thevenin model using Octave code to match laboratory data set
13. Tune an Rint model using Octave code to match laboratory data set
14. Manually tuning an ESC cell model

UNIT III - INTRODUCTION TO BATTERY MANAGEMENT SYSTEM (3T+6P)

Theory component:
-Battery Boot Camp - [8 Videos,13 Readings ,7 4 Quizzes/Assessment]
-How lithium-ion cells work - [7 Videos,7 Readings & 7 Quizzes/Assessment]
-BMS sensing and high-voltage control - [9 Videos, 9 Readings ,8 Quizzes/Assessment]
-BMS design requirements 2-5 - [8 Videos, 8 Readings,8 Quizzes/Assessment]
(Exclude Week 5 Content in the course)

Practical/Lab component: NA

UNIT IV - AC MOTOR CONTROL COMPONENTS, MOSFET & BATTERY SOC ESTIMATION (3T+6P)

Theory component:
-AC Motor Control Components - [1 Video] ? WEEK 2: 5TH TOPIC

-Power Semiconductor Switches (Ch.4.2) Power MOSFETs, MOSFET Gate Drivers, BJTs and IGBTs , More About Switching Loss, Wide Bandgap Power Semiconductors [1 Videos]
-What is the importance of a good SOC estimator - [8 Videos, 4 Readings, 7 Quizzes]
-Linear Kalman filter as a state estimator - [6 Videos, 6 Readings, 6 Quizzes]
-Linear Kalman filter - [7 Videos, 7 Readings, 7 Quizzes]
-Cell SOC estimation using an extended Kalman filter - [8 Videos, 8 Readings, 7 Quizzes]
-Cell SOC estimation using a sigma-point kalman filter - [7 Videos, 7 Readings, 6 Quizzes]
-Improving computational efficiency using the bar-delta method - [5 Videos, 5 Readings, 4 Quizzes]

Practical/Lab component:

1. Voltage based SOC estimation - LAB Exercise & Software Used for Practical Exercise This Jupyter notebook implements voltage-based methods for SOC estimation. This notebook implements two voltage-based SOC-estimation methods. The first one simply looks up cell terminal voltage under load in an OCV from SOC table. The second attempts to compensate for the effects of cell equivalent-series resistance
2. Generating correlated random vector
3. Sample code implementing linear Kalman filter
4. Simple EKF with octave code
5. Preparing to implement EKF on an ECM
6. Octave implementation of EKF to estimate SOC
7. Simple SPKF with Octave code
8. Octave implementation of SPKF to estimate SOC
9. Octave implementation of a bar-delta filter
10. Capstone project
    - ♦ Execute Capstone Project - Tuning an EKF for SOC Estimation
    - ♦ Execute Capstone Project - Tuning an SPKF for SOC Estimation

UNIT V - BATTERY STATE-OF ?HEALTH (SOH) ESTIMATION & MITIGATION OF HARMONICS (3T+6P)

Theory component:
-How does lithium-ion cell health degrade? - [8 Videos, 3 Readings, 3 Quizzes]
-Total-least-squares battery-cell capacity estimates - [7 Videos, 7 Readings, 7 Quizzes]
-How to write code for the different total-capacity estimators - [6 Videos, 6 Readings, 6 Quizzes]
-Introduction to Modeling and Control of Single-Phase Rectifiers and Inverters, Introduction to Grid-Tied Power Electronics, Low Hormonic Rectifiers, CCM and DCM Operation of the Boost Low-Harmonic Rectifier - [8 Videos,3 Readings,3 Quizzes]
-Control of the PFC Boost Rectifier, Input Voltage Feedforward Compensation, Loss- Free Resistor Model - [10 Videos,5 Practice Exercises]

Practical/Lab component:

1. Demonstrate estimate cell series resistance
2. Will be able to execute on finding the ordinary least squares solution as a benchmark
3. Execute ordinary-least-squares solution computationally efficient
4. Able to Find the solution to a weighted total-least-squares problem
5. Confidence intervals on least-squares solutions
6. Implement Simplifying the total-least-squares solution for cases having proportional uncertainties
7. Demonstrate Making simplifies solution computationally efficient
8. Finding solution to the AWTLS Problem
9. Write Octave code to estimate cell total capacity
10. Demonstrating Octave code HEV: Scenario 1
11. Demonstrating Octave code HEV: Scenario 2-3
12. Demonstrating Octave code BEV: Scenario 1
13. Demonstrating Octave code BEV: Scenario 2-3
14. Execute Robustness and Speed
15. Will be able to execute A Kalman filter approach to total capacity estimation

16. Access Matlab ; Demonstrate understanding of power factor and harmonics in the context of grid-tied power electronics. Assignment on Universal-Input Boost Low-Harmonic Rectifier
17. Assignment Quiz on DCM Flyback as PFC Rectifier, Demonstrate understanding of operating principles of low-harmonic, power factor correction rectifiers; Demonstrate ability to model single phase low harmonic rectifiers
18. Execute the Capstone Project - Tuning xLS algorithms for total capacity estimation & explore a different way to determine the "x" and "y" data you use as input to the total-capacity estimation methods.

TOTAL : 45 PERIODS

Mandatory Project work

1. Execute Capstone Project - Tuning an EKF for SOC Estimation Execute Capstone Project - Tuning an SPKF for SOC Estimation
2. Execute the Capstone Project - Tuning xLS algorithms for total capacity estimation & explore a different way to determine the "x" and "y" data you use as input to the total-capacity estimation methods.

Test Project :-

Design 48v 36Ah LIFEPO4 battery pack for the dimension of 430mm(L) x 15mm(B) x 160mm(H) and develop the control circuit for sensing the individual array temperature with OV and UV protection with minimum harmonic content also calculate the SOC and SOH using Octave model

Student Assessment Plan
o Every Sub-units will have a Quiz and every Unit will have an overall Graded Quiz other than Lab exercise and Capstone Projects o All Assessments are online based and self-graded o If a students does not score the required minimum of 80% , he will be asked to retake the tutorial and attempt the Quiz again.

Unit 1 ? Introduction to Electric Vehicles & Automation

1. Quiz on Mobility Terms
2. Quiz on Mobility ? Past, Present & Future
3. Quiz on EVs Made of?
4. Quiz on Battery Technology
5. Quiz on Stakeholders of Electrification

Overall Graded assessment on all the above topics

1. Quiz on Sustainability & Equity
2. Quiz on Impacts of Electrification
3. Quiz on Autonomous Vehicles Components
4. Quiz on Impacts of Automation

Unit 2 : ? Equivalent Circuit Cell Model Simulation

1. Quiz on Open-circuit voltage (OCV) and State-of-charge (SOC)
2. Quiz on How do we model voltage
3. Quiz on Warburg impedance & its implementations
4. Quiz on Convert a continuous-time model to discrete-time model
5. Quiz on Model parameter values
6. Quiz on Hysteresis in a lithium-ion cell and its modelling
7. Quiz on equivalent-circuit model of a lithium-ion cell

Overall assessment on all the above topics

1. Quiz on cell Characterization
2. Quiz on open-circuit voltage determination

3. Quiz on Cell?s coulombic efficiency and total capacity
4. Quiz on Cell?s temperature dependent OCV
5. LAB ? Jupyter notebook - To be used in Conjunction with Octave code to determine static part of ECM
6. Quiz on Octave code to determine static part of ECM
7. LAB ? Jupyter notebook - To be used in Conjunction with identifying parameters of static model and next steps
8. Quiz on Determining dynamic-model parameters
9. Quiz on cell data used to find dynamic-model parameter values
10. LAB ? Jupyter notebook to run for octave code to determine dynamic part of an ECM
11. Quiz on octave code to determine dynamic part of an ECM
12. LAB ? Jupyter notebook to run for octave code to simulate an ECM
13. Quiz on octave code to simulate an ECM
14. LAB ? Jupyter notebook to run for octave code to look up model parameter value
15. Quiz on octave code to look up model parameter value
16. LAB ? Jupyter notebook to run for octave code to compute OCV
17. Quiz on octave code to compute OCV

Overall assessment on all the above topics

1. LAB ? Jupyter notebook to run for ECM to simulate constant voltage
2. Quiz on how to use ECM to simulate constant voltage
3. LAB ? Jupyter notebook to run for ECM to simulate constant power
4. Quiz on how to use ECM to simulate constant power
5. Quiz on Simulate battery packs
6. LAB ? Jupyter notebook to run for Octave code to simulate PCM?s
7. Quiz on Octave code to simulate PCM?s
8. LAB ? Jupyter notebook to run for Octave code to simulate SCM?s
9. Quiz on Octave code to simulate SCM?s

Overall assessment on all the above topics

1. Quiz on develop a load/battery co-simulator
2. Assignment on how to Infer the information needed to develop a load/battery co-simulator based on the example taught.
3. Assignment on how to Analyze vehicle/battery co-simulation block diagram to understand the dependencies of simulation variables.
4. Quiz on Modelling ideal vehicle dynamins
5. Quiz on practical limits to model of vehicle dynamics Quiz on calculating electric-vehicle range
6. LAB ? Jupyter notebook to run for Octave code to set up EV simulation
7. LAB ? Jupyter notebook to run for Octave code to conduct EV simulation
8. Quiz on Octave code to set up EV simulation and conduct EV simulation
9. LAB ? Capstone Project to modify three sample Octave programs to create functions that can simulate temperature-dependent cells, battery packs built from PCMs, and battery packs built from SCMs.
10. Assignment ? Programming Assignment for manually tuning an ESC cell model

Unit 3 ? Introduction to Battery Management System

1. Pre-requisite Quiz on Battery Boot Camp
2. Quiz on battery terminology
3. Quiz on parts of electrochemical cell
4. Quiz on electro chemical cell storage and release energy
5. Quiz on materials to use in electrochemical cell

Overall assessment on all the above topics

1. Quiz on lithium-ion cells
2. Quiz on lithium-ion cells different from electrochemical cells

3. Quiz on negative electrodes for lithium-ion cells
4. Quiz on positive electrodes for lithium-ion cells
5. Quiz on electrolytes and separators for lithium-ion cells
6. Quiz on lithium to run out

Overall assessment on all the above topics

1. Quiz on primary functions of a BMS
2. Quiz on Modular design
3. Quiz on Cell Voltage in a BMS
4. Quiz on sense module temperature in a BMS
5. Quiz on sense battery-pack current in a BMS
6. Quiz on control contactors with a BMS
7. Quiz on electrical isolation in a BMS

Overall assessment on all the above topics

1. Quiz on BMS Protect the user and battery pack
2. Quiz on BMS interface with other system components
3. Quiz on BMS estimate SOC and SOH
4. Quiz on Cell SOC and Battery-pack SOC
5. Quiz on computing cell available energy and power
6. Quiz on computing battery pack available energy and power
7. Quiz on kinds of diagnostics must for a BMS report

Overall assessment on all the above topics

Unit 4 - AC Motor Control Components, MOSFET & Battery SOC Estimation

1. Quiz on AC motor control
2. Simulation of a Synchronous Boost Converter - Complete Assignment to Understand the tradeoff between voltage breakdown, switching time, and forward voltage drop in a power semiconductor device, Complete Assignment to Model switching loss using equivalent circuits
3. Complete Assignment to Design gate drivers, Work on LTspice File: Synchronous Boost Converter, with associated driver, dead time generator, and PWM models
4. Quiz on importance of a good SOC estimator
5. Quiz on defining SOC
6. Quiz on Estimating battery cell SOC
7. LAB - This Jupyter notebook implements voltage-based methods for SOC estimation. This notebook implements two voltage-based SOC-estimation

methods. The first one simply looks up cell terminal voltage under load in an OCV from SOC table. The second attempts to compensate for the effects of cell equivalent-series resistance

1. Quiz on man and covariance
2. Quiz on uncertainty of two unknown quantities
3. Quiz on varying uncertain quantities

Overall assessment on all the above topics

1. Quiz on predict/correct mechanism of sequential probabilistic inference
2. Quiz on Kalman-filter gain factor
3. Quiz on six steps of generic probabilistic inference
4. Quiz on three Kalman-filter prediction steps
5. Quiz on three Kalman-filter correction steps
6. Quiz on linear KF as a state estimator

Overall assessment on all the above topics

1. Quiz on Kalman filter with a linearized cell model
2. LAB ? Generate Correlated random vectors (15 Mins)
3. Quiz on Octave code to generate correlated random numbers
4. LAB ? Write Code implementing linear Kalman filter (15 mins)
5. Quiz on Octave Code to implement KF for linearized cell model
6. Quiz on numeric robustness of Kalman filter
7. Quiz on automatically detecting bad measurements with a Kalman filter
8. Quiz on initialize and tune a Kalman filter
9. Quiz on Linear KF and next steps
10. Quiz on Non-linear variations to Kalman filters
11. Quiz on three extended Kalman ?filter prediction steps
12. Quiz on three extended-Kalman-filter correction steps
13. LAB ? Write Simple EKF Example workout (20 Mins)
14. Quiz on Simple EKF with Octave code
15. LAB ? Preparing to implement EKF on an ECM (15 Mins)
16. Quiz on Preparing to implement EKF on an ECM
17. LAB ? Octave implementation of EKF to estimate SOC (30 Mins)
18. Quiz on Octave implementation of EKF to estimate SOC
19. Quiz on cell SOC estimation using an EKF and next steps
20. Quiz on Sigma point methods
21. Quiz on uncertain variables using sigma points
22. Quiz on six sigma ? point ?Kalman filter steps
23. LAB ? Simple SPKF example with Octave code (20 Mins)
24. Quiz on Simple SPKF example with Octave code
25. LAB ? Octave implementation of SPKF to estimate SOC (30 Mins)
26. Quiz on Octave implementation of SPKF to estimate SOC
27. Quiz on Cell SOC estimation using a SPKF and next steps
28. Quiz on estimating SOC for battery packs
29. Quiz on bar filters using an ECM
30. Quiz on delta filters using an ECM
31. LAB ? Octave implementation of a bar-delta filter (30 Mins)
32. Quiz on desktop validation as a method of predicting performance
33. Capstone Project Part 1 - Tuning an EKF for SOC Estimation Part 2- Tuning an SPKF for SOC Estimation

Unit 5 :- Battery State-of ?Health (SOH) Estimation & Mitigation of harmonics ? (10 Hours)

1. Quiz on cell ages
2. Quiz on Negative-electrode aging processes at particle surface
3. Quiz on Negative-electrode aging processes in bulk and composite electrode
4. Quiz on positive-electrode aging processes
5. LAB - This Jupyter notebook implements ### Simple method to estimate cell series resistance. This notebook executes the simple method presented in lesson 4.1.6 to estimate cell series resistance
6. Quiz on cell voltage to changes in equivalent series resistance (ESR) (10 Mins) Quiz on sensitivity of cell voltage to changes in cell total capacity

Overall assessment on all the above topics

1. Quiz on using ordinary least squares to estimate total capacity
2. LAB ? How to find the ordinary least squares solution as a benchmark (10 Mins)
3. Quiz on ordinary least squares solution as a benchmark
4. LAB ? Demonstrating the ordinary-least-squares solution computationally efficient (10Mins)
5. Quiz on ordinary-least-squares solution computationally efficient
6. LAB ? Finding the solution to an weighted total-least-squares problem (10 Mins)
7. Quiz on setting up weighted total-least-squares solution
8. LAB ? Confidence intervals on least-squares solutions (10 Mins)

9. Quiz on Confidence intervals on least-squares solutions

Overall assessment on all the above topics

1. LAB ? Simplifying the total-least-squares solution for cases having proportional uncertainties (10 Mins)
2. Quiz on the total-least-squares solution for cases having proportional uncertainties
3. LAB ? Making simplifies solution computationally efficient (10 Mins)
4. Quiz on Making simplifies solution computationally efficient
5. Quiz on Defining geometry for approximate full solution to weighted total least squares
6. Quiz on finding appropriate cost function for approximate full solution to AWTLS problem
7. LAB ? Finding solution to the AWTLS Problem (10 Mins)
8. Quiz on AWTLS Problem
9. LAB ? Adding fading memory (10 Mins)

Overall assessment on all the above topics

1. LAB ? Write Octave code to estimate cell total capacity (10 Mins)
2. Quiz on estimate cell total capacity
3. LAB ? Demonstrating Octave code HEV: Scenario 1 (10 Mins)
4. Quiz on Octave code HEV: Scenario 1
5. LAB ? Demonstrating Octave code HEV: Scenario 2-3 (10 Mins)
6. Quiz on Octave code HEV: Scenario 2-3
7. LAB ? Demonstrating Octave code BEV: Scenario 1 (10 Mins)
8. Quiz on Octave code BEV: Scenario 1
9. LAB ? Demonstrating Octave code BEV: Scenario 2-3 (10 Mins)
10. Quiz on Octave code BEV: Scenario 2-3

Overall assessment on all the above topics

1. Quiz on Deriving SPKF method for parameter estimation
2. Quiz on Deriving EKF method for parameter estimation
3. Quiz on estimate states and parameters at the same time. Steps to do
4. LAB ? Robustness and Speed (1 hour)
5. LAB ? A Kalman filter approach to total capacity estimation (10 Mins)
6. Capstone Project Evaluation ? Students have learned several different total-capacity estimation methods. Some of these methods work better than others in general, but any method is only as good as the data you give it. In this project, students will explore a different way to determine the "x" and "y" data you use as input to the total-capacity estimation methods. (3 hr. 30 Mins)
    - ♦ Jupyter notebook for capstone project integrated
    - ♦ Tuning xLS algorithms for total capacity estimation
7. Quiz on Universal-Input Boost Low-Harmonic Rectifier
8. Quiz on DCM Flyback as PFC Rectifier
9. Quiz on Energy Storage Capacitor in a Flyback PFC
10. Quiz on Boost PFC Rectifier Control Loops
11. Quiz on Comparison of PFC Rectifiers

Test Project :-

Design 48v 36Ah LIFEPO4 battery pack for the dimension of 430mm(L) x 15mm(B) x 160mm(H) and develop the control circuit for sensing the individual array temperature with OV and UV protection with minimum harmonic content also calculate the SOC and SOH using Octave model

COURSE OUTCOMES

Students will be able to

1. Arrange the Cell array for various power ratings

2. Measure the Voltage, Current and temperature of individual cell array
3. Estimate the fault current during short circuit and overload
4. Develop the galvanizing isolation for high and low side MOSFET
5. Estimation of SOC and SOH
6. Estimation of SOC and SOH
7. Develop protection circuit for fast charging
8. Mitigation of harmonics in EV charging system

Course Links

1. [1]
2. [2]
3. [3]
4. [4]
5. [5]
6. [6]
7. [7]
8. [8]