24-643 || 27-700

Energy Storage Materials & Systems

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HW 5:
Battery Packs for EVTOL aircraft
Due: December 10, 2021

(This document has 2 pages)

In this homework, we will analyze how to design battery packs for EVTOLs by understanding the intricate link between the application and choice of the battery chemistry and its performance. You are a battery engineer who has been offered a gig to design the battery pack for one of the five EVTOL manufacturers. You may choose one of the five EVTOL aircraft to design the battery pack and build a battery model.
Supporting materials are available at `https://github.com/tinosulzer/CMU_energy_storage_HW5`

1. Analyze the cell specification sheet for the LGM50 cell and calculate the cell performance metrics: (i) Cell nominal voltage, (ii) Cell nominal capacity, (iii) Max discharge rate (in A), (iv) Cell specific energy, (v) Cell specific power, and (vi) Voltage limits of operation.

2. Fit an RK polynomial for the open-circuit potential of each electrode as a function of electrode state of charge (or 'stoichiometry'), using the data provided

3. Using PyBaMM, simulate a full constant-current discharge of the LGM50 cell at 1C, and plot current and voltage. For this question, use your RK polynomial from Q3 together with the parameter set provided for other parameters (see template notebook).

4. For a typical mission using each of the 5 EVTOL designs,

   (a) Plot the power versus time.

   (b) Calculate the total battery pack power capacity and peak pack power required for the chosen EVTOL aircraft.

   (c) Calculate the total number of (LGM50) cells required to construct the battery pack for the chosen EVTOL aircraft based on (i) total energy required and (ii) peak power required

5. Simulate your assigned EVTOL mission in PyBaMM
   (see `mission_assignments.txt`).

(a) What is the power required from each cell to complete the EVTOL mission, based on your answer to 4c)i)?

(b) Write the EVTOL mission for a single cell as a PyBaMM experiment. You can model each segment as constant-power using the mean power over that segment.

(c) Using PyBaMM, simulate the EVTOL mission and plot current and voltage

(d) Comment on the performance of the cell under the EVTOL mission.

6. What is a better way to choose the number of cells in the pack? Adjust the number of cells in the pack so that the mission can be completed, and repeat Q5 with this new number

7. Calculate the total weight of the final battery pack including added weight for battery packaging, thermal management system and other auxiliary systems. Cite a relevant reference/source for calculating the added weight. What is the total weight remaining (if any) for payload in the chosen aircraft? (assume that payload + batteries = 0.6 * max takeoff mass)

8. Determine the number of cells that minimizes the total battery weight while allowing the EVTOL mission to remain feasible. What is the total weight remaining for payload with this many cells?

9. What is the rate-limiting factor for this chemistry? You are now tasked with designing a battery that can better handle the EVTOL mission. Which parameter(s) should you modify in order to reduce the number of cells required and hence increase the payload? Change up to two parameters by a factor of up to 10, and repeat Q8.

10. Define a CCCV charging protocol based on the specification sheet. Simulate this CCCV charge using PyBaMM. How long does it take to charge the EVTOL aircraft to 99% SOC between missions using this protocol? (Hint 1: use the `initial_soc` argument in `Simulation.solve` to simulate charging from empty. Hint 2: SOC can be calculated using the 'Discharge capacity [A.h]' variable and the nominal cell capacity)

11. Suggest a battery chemistry that may have been better suited for this application, with justification.

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