Electric Energy Storage and New Energy Sources for Electric Vehicles (EE546)

Assignment

Question 1 (50%)

Please answer the following questions regarding batteries:

1) A battery has an electromotive force E=3.7 V. The ohmic resistance is R_Ω=50 mΩ, and the polarization resistance is R_f=30 mΩ.
   i. Calculate the working voltage U_{cc} when the discharge current is I=2 A.
   ii. Recalculate the working voltage U_{cc} when the discharge current is I=6 A.
   iii. Compare the two results and briefly explain how the external load current influences the working voltage of the battery.
2) List three types of primary (non-rechargeable) cells and five types of secondary (rechargeable) cells. In general, which type of battery has higher specific energy (i.e., holds more energy in Wh/kg)?
3) An electric vehicle's battery system needs to meet the following requirements:
   Bus voltage: 800 V
   Total energy capacity: 96 kWh
   Given the parameters of a single battery cell:
   Rated voltage: 3.7 V
   Rated capacity: 3 Ah
   Questions:
   i. Please calculate the series number N_s and the parallel number N_p to achieve the required bus voltage and the required total capacity.
   ii. How long can the vehicle discharge at a rate of 2C?
   iii. What is the maximum power of the battery system at 1C discharge rate?

Question 2 (50%)

Please answer the following questions regarding supercapacitors:

1) The capacitance of a capacitor can be expressed as $C=\varepsilon A/d$. Based on this relationship, answer the following questions related to electric double-layer capacitors (EDLCs).
   i. List four types of electrode materials typically used by EDLCs to maximize the effective surface area A, and what properties of these materials contribute to a large A?
   ii. According to the Helmholtz model, what is the approximate distance d of the electrical double-layer (EDL)?
2) Answer the following questions related to cyclic voltammetry (CV) testing:
   i. What is the shape of the CV curve of an ideal capacitor, and why does the actual CV curve of a supercapacitor deviate from this ideal case? Give two reasons for such deviations.
   ii. In a CV test for a supercapacitor with a mass of 40 g, a voltage window ΔU=2.5 V, and an integrated charge ΔQ=300 C, calculate the specific capacitance of the device based on the CV test data.
3) Answer the following questions related to Galvanostatic charge/discharge (GCD) using a current of 3 A:
   i. If a sudden drop of 0.15 V in potential is observed at the moment of transition from charging to discharging, what is the equivalent series resistance (ESR) of the supercapacitor?
   ii. From the perspective of maximum power density explain why a smaller ESR is beneficial for supercapacitor performance.