EE546 Homework 1

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Question 1:

1):

Given:

$$\begin{aligned} Electromotive force(EMF)\ :&E = 3.7V \\ Ohmic resistance\ :&R_{\Omega} = 50m\Omega = 0.05\Omega \\ Polarization resistance\ :&R_f = 30m\Omega = 0.03\Omega \end{aligned}$$

$$R_i = R_{\Omega} + R_f = 0.05 + 0.03 = 0.08\Omega$$

1.When discharge current I = 2 A:

$$\begin{aligned} U_{cc} &= E - IR_i \\ &= 3.7 - 2\times 0.08 = 3.7 - 0.16 = 3.54V \end{aligned}$$

2.When discharge current I = 6 A:

$$\begin{aligned} U_{cc} &= E - IR_i \\ &= 3.7 - 6\times 0.08 = 3.7 - 0.48 = 3.22V \end{aligned}$$

3. Comparison and explanation:

- When current increases from 2A to 6A, the operating voltage decreases from 3.54V to 3.22V, a drop of 0.32V
- Reason: Higher external load current results in greater voltage drop across the internal resistance, leading to reduced output voltage

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2)

Primary batteries (non-rechargeable):

1. Zinc–carbon
2. Alkaline Battery
3. Li-Metal Battery

Secondary batteries (rechargeable):

1. Ni-Cd Battery
2. Ni-Fe Battery
3. Ni-MH Battery
4. Lead Acid Battery
5. Lithium-Ion Battery

Energy density comparison:

- Primary batteries typically have higher specific energy density because they don't need to consider reversibility, allowing for more active materials and optimized chemical reactions

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3)

Given:

- Bus voltage: 800 V
- Total energy capacity: 96 kWh
- Single cell(Rated voltage,Rated capacity): 3.7 V, 3 Ah

1. Series and parallel configuration calculation:

$$Seriesnumber : N_s = 800V/3.7V = 216.2 \approx 217cells$$
$$Parallelnumber \ \ N_p \ \ = (96kWh/800V)/3Ah = 120Ah/3Ah = 120Ah/3Ah = 40$$

2. 2C discharge time:

$$\begin{aligned} t_{discharge\ time} &= \frac{Total \ \ capacity}{2C \ \ discharge \ \ current} \\ &= 120Ah/(2*120)A \\ &= 0.5hours = 30minutes \end{aligned}$$

3. Maximum power at 1C discharge:

$$\begin{aligned} P_{maximum} &= (1C \ \ discharge \ \ current) * V_{bus \ \ voltage} \\ &= 800V \times 120A = 96kW \end{aligned}$$

Question 2:

1)

1. Four electrode materials(EDLC):

- Activated carbon:activated carbon has very large specific surface area.
- Carbon nanotubes : tubular nanostructure, high conductivity, stable framework.
- Carbon Aerogel: highly porous and lightweight, specific surface area 100–1000 m^2/g, performance can be enhanced through surface modification.
- Carbon nanofiber: graphitized structure, can be composited with other materials to enhance electrochemical performance

Properties to a large A:

- Unique molecular structure ,porous structure.

2. Electric double layer distance(EDL):

The electrical double layer distance d is on the order of the ionic radius, Typical values range from 31 pm to over 200 pm .ionic_radius_from_wiki

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2)

1. CV curve characteristics:

Ideal capacitor: Rectangular shape for CV curve.

Reasons for practical deviations:

1. Capacitor with resistivity lead to a diamond shape.
2. Due to influence of redox reactions,cause peaks in cv curve .

2. Specific capacitance calculation:

$$mass: \quad m = 40g,$$
$$voltagewindow: \Delta U = 2.5V,$$
$$integratedcharge: \Delta Q = 300C$$

$$\begin{aligned} C_s &= \mathit{\Delta} Q/(m \times \mathit{\Delta} U) \\ &= 300C/(40g \times 2.5V) = 3F/g \end{aligned}$$

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3)

i. Equivalent series resistance calculation:

$$current: \quad I = 3A$$
$$voltage \;\; drop: \Delta V = 0.15V$$

$$ESR: R_s = \Delta V/(2I) = 0.15V/(2 \times 3)A = 0.025\mathit{\Omega} = 25m\mathit{\Omega}$$

2. ESR impact on power density:

Maximum power density analysis:

- Power: $P = U^2/(4 \times ESR)$ (maximum power when load resistance equals internal resistance)

$$P = \frac{U^2}{(4 \cdot R_s)}$$

- Lower ESR means:
  - Lower power loss (I^2R loss).
  - Higher operating voltage (reduced IR drop).
  - Faster charge-discharge response.
  - Achieving higher instantaneous power output under high current conditions.
