1. Calendar life degradation : 2% / year
Cycle life degradation = 0.05% / cycle
Annual driving distance : 20,000 km/year
Energy consumption per year : 200 Wh/km

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(a) $E_{year} = 20{,}000 km \times 200 Wh = 4000 kWh/year$

$$N_{cycles/year} = \frac{E_{year}}{E_{pack}}$$

lets Assume $E_{pack} = 72 kWh$ as per example 2.

$$N_{cycles/year} = \frac{4000 kWh}{72 kWh} \approx 55.55 = 56 \text{ cycles/year}$$

(b) Total degradation = 5 years × 2% = 10% (Calendar loss)

Cycle loss = $0.05\% \times 5 \text{ years} \times \frac{4000 kWh}{72 kWh} = 14\%$

Total Capacity loss = 10% + 14% = 24%

(c) Total allowable degradation = 100% - 80% = 20%

loss per year = $2\% + (0.05\% \times 56) = 2\% + 2.8\% = 4.8\%$

Time taken to reduce to 20% = $\frac{20\%}{4.8\%} \approx 4.2$ years

2. 96S20P Cell mass = 48g $C_p = 3.8 kJ/kg \cdot K$ $R_{int} = 0.01\Omega$
Discharge current per string = 120A $t_{max} = 45°C$ Cool plate temp: 25°C
Allowed coolant temp rise = 5°C
Coolant : $C_{p,coolant} = 3.6 kJ/kg \cdot K$, $\rho = 1050 kg/m^3$

1. Power loss per cell

20 cells in parallel $= \frac{120A}{20} = 6A$

$$P_{cell} = I^2 \cdot R = 6^2 A \cdot 0.01\Omega = 0.36\,W$$

2. Heat generated per pack

$$N_{cells} = 96 \times 20 = 1920$$

Total power loss, $Q_{total} = 1920 \text{ cells} \times 0.36W = 691.2W$

3. Coolant mass flow rate required

For steady state heat transfer, $Q = \dot{m} \times C_p \times \Delta T$ (mass flow rate)

$$\dot{m} = \frac{Q}{C_p \times \Delta T} = \frac{691.2\,W}{3.6\,KJ/kg\cdot K \times 5^\circ C} = 0.0384\ kg/s$$

4. Volumetric flow rate.

$$\dot{V} = \frac{\dot{m}}{\rho} = \frac{0.0384\ kg/s}{1050\ kg/m^3} = 3.66 \times 10^{-5}\ m^3/s = 2.20\ L/mins.$$

5. Cell temp. rise for thermal resistance

$$\Delta T_{cell} = P_{cell} \cdot R_{th} = 0.36W \times 0.15K/W = 0.054^\circ C$$

Final design Summary:

Total power loss = 691.2W

Required coolant mass flow rate = 0.0384 kg/s

volumetric flow rate = 2.20 L/min

Cell-cold plate temp rise = 0.054°C

Coolant temp. rise = 5°C (Given).

Manifold system

→ Can use parallel manifold system with 6-8 parallel branches with each branch feeding 12-16 cold plates

Capable of delivering ≥ 2.20L/min, in compatibility with ethylene glycol

Thermally coupled to each cells

Pump → Manifold → Cold plates (x96) → Manifold return

Pump ↓ Reservoir for coolant

Manifold return ↓ Heat exchanger / Fan cooled radiator (sized for ≥700W dissipation at 5°C ΔT) → Reservoir for coolant