Assignment 3

EV355

Ayush Tandon
2K22/CO/133

Q.1.) $V_{oc} = 12V$, $R_I = 0.2\Omega$, $R_{Load} = 10\Omega$, $I = 1A$

$V_{Terminal} = V_{oc} - IR_I = 12 - (0.2 \times 1) = \underline{11.8V}$

(a) Terminal Voltage $= \underline{11.8V}$

(b) Power Delivered to Load

$P_{Load} = I_L^2 \times R_{Load}$

$= 1 \times 10 = \underline{10W}$

Q.2.) BEV

Annual Distance = 24000 Km.

Lifetime index $\Rightarrow L = 1$

Cell capacity = 3.4 Ah

Cell voltage = 3.6 V

Energy consumption = 204 Wh/Km.

(i) Beginning of life (BOL) KWh storage.

$E_{annual} = 24000 \times 204$ Wh/year $= \underline{4896 \text{ KWh/year}}$

Total energy for 8 years $= 8 \times 4896 = 39168$ KWh.

BOL storage = 39168 KWh

Q2) (ii) Energy capacity of one cell $E_{cell} = V_{cell} \times C_{cell} = 3.6 \times 3.4$

$$\boxed{E_{cell} = 12.24 \text{ Wh/cell}}$$

$$\text{Total cells} = \frac{E_{Total}}{E_{cell}} = \frac{39168 \times 10^3}{12.24} = 32{,}00{,}000 \text{ cells}$$

$$\text{Range} = \frac{\text{Battery Energy}}{\text{Energy Consumption}} = \frac{39.168}{0.204} \approx 192 \text{ Km}$$

Range = 192 Km

(iii) $E_{required} = 425 \times 204 = 86700 \text{ Wh} = 86.7 \text{ KWh}$
for 425 Km.

$$\text{Total Cells} = \frac{86700}{12.24} = 7085 \text{ cells}$$

7085 cells are required for range of 425 Km.

(iv) $$\text{Parallel Strings} = \frac{\text{Total Cells}}{\text{cell in Series}} = \frac{7085}{96} \approx 74 \text{ strings}$$

74 parallel strings.

(v) $$\text{Pack Mass} = \frac{\text{Pack Energy}}{\text{Energy Density}} = \frac{86700}{150} \approx 578 \text{ Kg}$$

Battery pack mass is 578 Kg.

(vi) Power to Energy Ratio

Peak power → 325 KW Energy → 86.7 KWh.

$$P/E = \frac{325}{86.7} \approx 3.75$$

Power to Energy Ratio → 3.75

$$\Delta I_L = \frac{288\,(1-0.0443)}{100 \times 245 \times 10^{-6}} = 65.53\,A$$ Ripply current

RMS current $I_{cap/rms} \approx \frac{\Delta I_L}{\sqrt{12}} = \frac{65.53}{\sqrt{12}} = 18.91\ A$

(ii) ⇒ Average current

$$I_{Avg/IGBT} = D \cdot I_L = 0.443 \times 104.17$$
$$= 46.13\,A$$

Diode ↘ $J_{Avg/Diode} = (1-D)\,I_L = (0.557) \times 104.17$
$$= 58.03\ A$$

• RMS current

$$I_{RMS/IGBT} = I_L\sqrt{D} = 69.46A$$

$$I_{RMS/Diode} = I_L\sqrt{1-D} = 104.17 \times \sqrt{0.557}$$
$$= 78.27A$$

• Maximum Inductor Current

$$I_{max} = I_L + \frac{\Delta I_L}{2} = 104.17 + \frac{65.53}{2} = 136.93\,A$$

• Minimum Inductor Current

$$I_{min} = I_L - \frac{\Delta I_L}{2} = 104.17 - \frac{65.53}{2} = 71.40\,A$$

(iii) RMS current in high capacitor voltage.

$$I_{cap,RMS} = \frac{\Delta I_L}{\sqrt{12}} = 18.91\ A$$

(iv) Low Voltage Capacitor

$$\Delta V = \frac{\Delta I_L}{f_s\, C_{Low}}$$

$$C_{Low} = \frac{\Delta I_L}{\Delta V f_s} = \frac{65.53}{0.005 \times 288 \times 10{,}000} = 45.47\ \mu F$$

$$C_{High} = \frac{\Delta I_L}{\Delta V \cdot f_s} = \frac{65.53}{0.005 \times 650 \times 10{,}000} = 20.12\ \mu F$$

Q.3.) 10,000 cycles 60Wh/year 10 years
Cell capacity = 6.5 Ah Cell Voltage = 1.2 V L = 1.5

(i) BOL Battery Pack Energy storage

$E_{Total} = 10000 \times 60 = \underline{600 kWh.}$

(ii) Total Number of cells

$E_{cell} = V_{cell} \times C_{cell} = 6.5 \times 1.2 = 7.8\ Wh/cell$

$\text{Total Cells} = \frac{600\ kWh}{7.8\ Wh/cell} = \underline{76923 \text{ cells}}$

(iii) ⟹ Pack Voltage

$\text{Pack Voltage} = \text{Cell in series} \times V_{cell} = 76923 \times 1.2 V$

(iv) P/E ratio $P/E = \frac{30}{600} = \underline{0.05}$ Ans

Peak power = 30kW

Peak Energy = 600kWh

Q.4.) Hybrid Electric Vehicle P = 30kW $V_{DC} = 650 V = V_{Low}$

$L = 245 \mu H$, $f_s = 10 kHz$ {switching frequency} $V_{Battery} = 288V = V_{High}$

Buck Converter

(i) RMS currents

$I_L = \frac{P}{V_{Battery}} = \frac{30000}{288} = \underline{104.17A}$

Ripple Current $\Delta I_L = \frac{V_{Low} \times (1-D)}{L \cdot f_s}$

$D = \text{Duty Cycle} = \frac{V_L}{V_H} = \frac{288}{650} = \underline{0.443}$

Q.5) $V_{in} = 85V$ to $265V$ $V_o = 400V$

$P_{out} = 1650W$ $f_s = 70KHz$ $\Delta V_o = 0.1 V_o = 40V$

(i) Minimum Inductance

$$L_{min} = \frac{V_{in(min)}\,(V_o - V_{min})}{V_o \cdot \Delta I_L \cdot f_s}$$

$$\Delta I_L = \frac{2P_o}{V_o} = \frac{2 \times 1650}{400} = 8.25A$$

$$L_{min} = \frac{85 \times (400 - 85)}{400 \times 8.25 \times 70 \times 10^3} = 17\,mH$$

(ii) → Low frequency Ripple Current

$$\Delta I_{c\,(low)} = \frac{2P_o}{V_o} = 8.25A$$

(iii) → High frequency Ripple Current

$$\Delta I_{c\,(high)} = \frac{\Delta V_o \cdot f_s \cdot C}{V_o} \Rightarrow \frac{40 \times 70 \times 10^3 \times 6570 \times 10^{-6}}{400}$$

$$\Delta I_{c\,(high)} = 45.99\,A$$

(iv) Capacitance Value

$$C = \frac{\Delta I_{c\,(low)}}{2\pi f_{line} \Delta V_o} = \frac{8.25}{2\pi (50)(40)} = 6570\mu F$$

assuming $f_{line} = 50Hz$

Q.6) $V_i = 125V$, $V_f = 100V$ $E = \frac{1}{2} C \Delta(V)^2 = \frac{1}{2} \times 1 \times ((125)^2 - 100^2)$

$$\boxed{E = 2812.5J}$$

Energy Released $= 2812.5J$ during discharge.

Q.7) Discharge current $= 100A$, $V_i = 125V$, $V_f = 45V$

$$t = \frac{C \cdot (V_i - V_f)}{I} = \frac{(125 - 45)}{100} = 0.8\,sec$$

Q.8.) $V_i = 125\,V$ to $V_f = 75\,V$, $t = 300\,sec$

Discharge current $I = \frac{C(V_i - V_f)}{t} = \frac{125-75}{300}$

for $C = 1F$ $I = 1/6 = \underline{0.167\,A}$

Discharge current $= 0.167\,A$.