EE2022 ELECTRICAL ENERY SYSTEMS

(Tutorial #5 solutions)

Solution Q1:

The reverse saturation current is

$$I_0 = 2 \times 10^{-12} A/cm^2 \times 100cm^2 = 2 \times 10^{-10} A$$

(a) At full sun the short circuit current is
$$I_{SC} = 20 \times 10^{-3} A/cm^2 \times 100cm^2 = 2A$$

The open circuit voltage is

$$V_{OC} = 0.0257 \ln\left(\frac{I_{sc}}{I_0} + 1\right) = 0.0257 \ln\left(\frac{2}{2 \times 10^{-10}} + 1\right) = 0.591\,V$$

(b) At half sun the short circuit current is
$$I_{SC2} = 20 \times 10^{-3} A/cm^2 \times 100cm^2 / 2 = 1A$$

The open circuit voltage is

$$V_{OC} = 0.0257 \ln\left(\frac{I_{SC2}}{I_0} + 1\right) = 0.0257 \ln\left(\frac{1}{2 \times 10^{-10}} + 1\right) = 0.573\,V$$

Solution Q2:

From the equivalent circuit,

$$\mathrm{I} = \mathrm{I_{SC}} - \mathrm{I_d}$$

$$\mathrm{I_d} = \mathrm{I_o}\left(e^{\frac{qV}{KT}} - 1\right)$$

$$\mathrm{I} = \mathrm{I_{SC}} - \mathrm{I_o}\left(e^{\frac{qV}{KT}} - 1\right)$$

(a) At the open circuit voltage, $\mathrm{I} = 0$ and $\mathrm{V} = \mathrm{V_{OC}}$

$$0 = \mathrm{I_{SC}} - \mathrm{I_o}\left(e^{\frac{qV_{OC}}{KT}} - 1\right)$$

At 25°C,

$$\mathrm{V_{OC}} = 0.0257 \ln\left[\frac{\mathrm{I_{SC}}}{\mathrm{I_o}} + 1\right] = 0.533\mathrm{V}$$

(b) At $\mathrm{V} = 0.5\mathrm{V}$,

$$\mathrm{I} = \mathrm{I_{SC}} - \mathrm{I_o}\left(\mathrm{e}^{\frac{\mathrm{qV}}{\mathrm{KT}}} - 1\right)$$

$$\mathrm{I} = 1 - 10^{-9}(\mathrm{e}^{38.9\times0.5} - 1) = 0.72\mathrm{A}$$

(c) At $\mathrm{V} = 0.5\mathrm{V}$,

$\mathrm{I} = 0.72\mathrm{A}$

$\mathrm{P} = \mathrm{VI}$

$\mathrm{P} = 0.5 \times 0.72 = 0.36\mathrm{W}$

(d) At $\mathrm{V} = 0.5\mathrm{V}$,

Power Output = 0.36W

Power Input = Area × Insolation = 0.005 × 1000 = 5W

(e) Efficiency of the cell = $\frac{0.36}{5} \times 100\% = 7.2\%$

Solution Q3:

Using V_d = 0.50 V the current is

$$I = I_{SC} - I_0\left(e^{38.9V_d} - 1\right) - \frac{V_d}{R_P} = 4 - 10^{-9}\left(e^{38.9*0.5} - 1\right) - \frac{0.5}{5} = 3.62A$$

The total voltage of the module is

V_{module} = $n\left(V_d - I * R_s\right) = 40\left(0.5 - 3.62 * 0.01\right) = 18.552\ V$

Total power delivered by the module is

P(watts) = $V_{\text{module}}\ I$ = 18.552 X 3.62 = 67.158 W

Solution Q4:

(a) Average power in the wind

$$P = \frac{1}{2}\rho A V^3$$

$$P = \frac{1}{2} \times 1.225 \times \pi \times \frac{20^2}{4} \times 10^3 = 192.423kW$$

Power generated from the wind turbine at 10 m will be P_{10} = $0.3 \times 192.423kW = 57.73kW$

(b) At a height of 250 m, the wind velocity can be approximated using:

$$\frac{v}{v_o} = \left(\frac{H}{H_o}\right)^{\alpha}$$

Using, $\alpha = 0.3$

$$\frac{10}{v_{250}} = \left(\frac{10}{250}\right)^{0.3}$$

$$v_{250} = 26.265\ m/s$$

Average power in the wind at 250 m:

$$P = \frac{1}{2} \times 1 \times \pi \times \frac{20^2}{4} \times (26.265)^3 = 2846.2kW$$

Power generated = $0.3 \times 2846.2kW = 853.86kW$

Solution Q5:

a. Using the formula below we can calculate the wind velocity at different heights.

$$\frac{v}{v_o} = \left(\frac{H}{H_o}\right)^{\alpha}$$

For surface with crops, hedges and shrubs, $\alpha = 0.2$

$$\frac{5}{v_{90}} = \left(\frac{10}{90}\right)^{0.2}$$

$$v_{90} = 7.76\ m/s$$

The specific power can be calculated as follows:

$$\frac{P}{A} = \frac{1}{2}\rho V^3$$

$$\frac{P}{A} = 0.5 \times 1.225 \times 7.76^3 = 286.214\ W/m^2$$

(b)

$$\frac{5}{v_{30}} = \left(\frac{10}{30}\right)^{0.2}$$

$$v_{30} = 6.23\ m/s$$

$$\frac{P}{A} = \frac{1}{2}\rho V^3$$

$$\frac{P}{A} = 0.5 \times 1.225 \times 6.23^3 = 148.105\ W/m^2$$

(c) This example illustrates an important point about the variation in windspeed and power across the face of a spinning rotor. For large machines, when a blade is at its high point, it can be exposed to much higher wind forces than when it is at the bottom of its arc. This variation in stress as the blade moves through a complete revolution is compounded by the impact of the tower itself on windspeed especially for downwind machines, which have a significant amount of wind “shadowing” as the blades pass behind the tower. The resulting flexing of a blade can increase the noise generated by the wind turbine and may contribute to blade fatigue, which can ultimately cause blade failure.