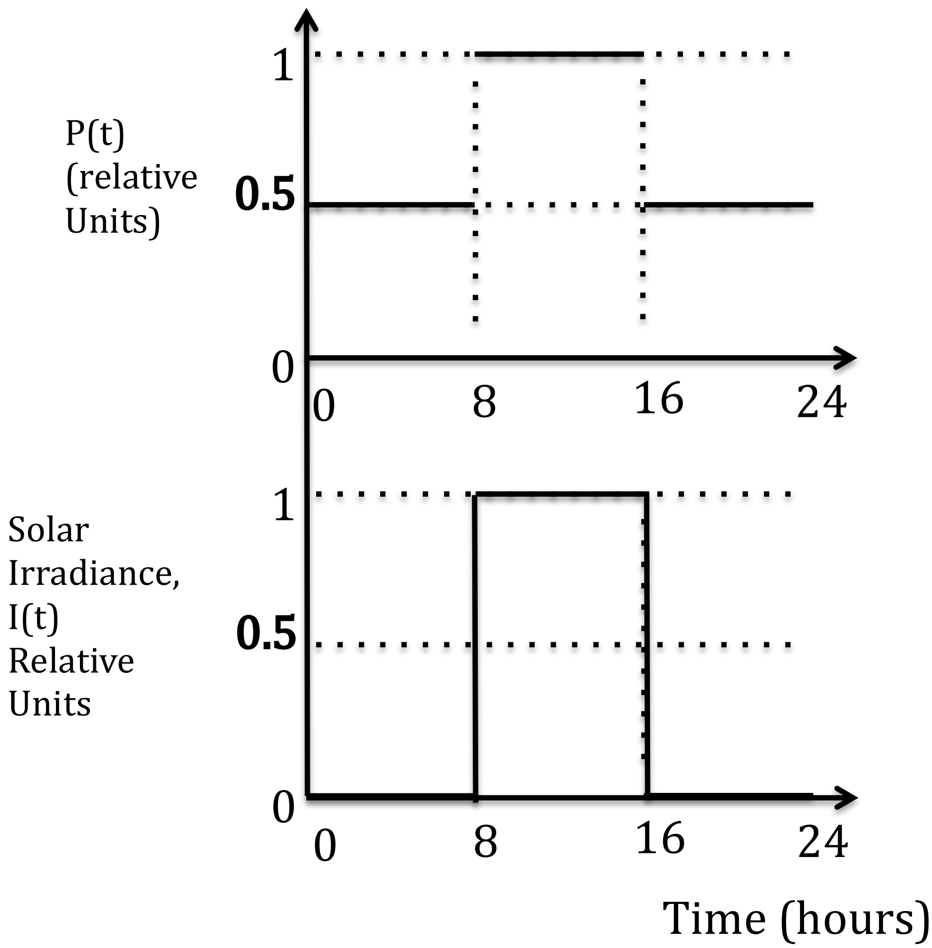
MAE 119 Winter 2013
Prof. G.R. Tynan
Quiz 5

You have been tasked with doing the conceptual design analysis of a solar PV system to power a village in a developing country with a population of 10,000. The per-capita time-averaged power demand is 400 Watts. When the sun has an intensity of 1000 W/m^2 . the available PV cells have an open circuit voltage V_{OC} =0.5 V and a short circuit current I_{sc}=20 mA/cm^2 with an I-V curve form factor FF=1. The power demand, P(t), and solar irradiance, I(t), vary in time according to:

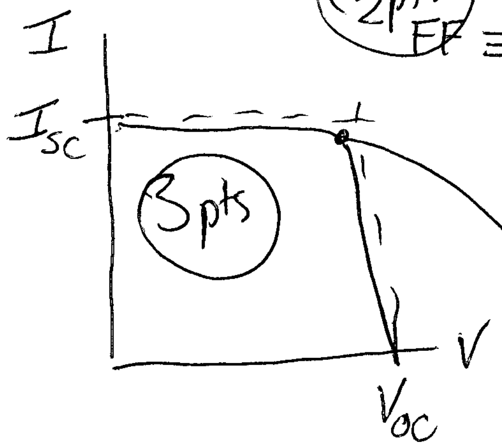


a) For a general power demand, P(t), what is the total amount of energy production needed for a one-day period? (5 points)
b) Plot the solar cell I-V curve for this idealized case, and identify the point of maximum power production. (5 points)
c) Find the total required solar panel area required to meet the total energy demand if the peak solar intensity is 1000 W/m^2 and P(t) and I(t) follow the curves shown above. (5 points)
d) Find the total required capacity of the energy storage system. (5 points)

MAE 119 Quiz 5 Solution

1. $E_{tot} = \int_0^T P(t)\,dt$, where $T = 1$ day   5 PTS

2.



(2pts) $FF \equiv \dfrac{V_{MP} I_{MP}}{V_{OC} I_{SC}} = 1 \Rightarrow$ I–V is nearly square

(5pts)

3. Panel Area?

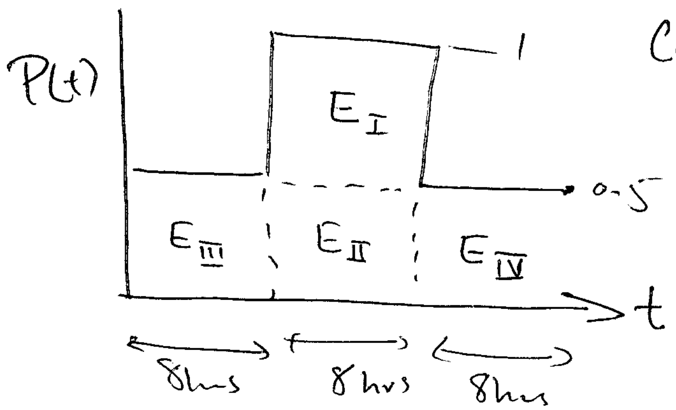
$P_{ave} = 400 \frac{W}{person} \cdot 10^4$ people $= 4$ MW   (1pt)

with $I_{SC} = 20 \frac{mA}{cm^2}$ $V_{OC} = 0.5V$ $FF = 1$

we have $\eta = \dfrac{\cancel{20}\,(10)\, 10^{-3} \frac{A}{cm^2} \cdot 10^4 \frac{cm^2}{m^2}\, \cancel{0.5}\,V}{1000\ W/m^2}$

$\longrightarrow \eta = 10\%$

(c)



Consider $\int P(t)dt$ to be given by the areas $E_I, E_{II}, E_{III}, E_{IV}$ as shown. we have

$$E_I = E_{II} = E_{III} = E_{IV} = \frac{1}{4} E_{tot}$$

~~= 1 MW · 8hrs = 8 MW-hrs~~

& their sum is just E_{tot}

$$E_{tot} = P_{ave} \cdot \Delta t \Big|_{1 day} = 4 MW \cdot 24 \text{ hrs}$$

(2 pts) $= \underline{96 \text{ MW-hrs}}$ of energy/day

$\therefore E_I = \underline{24 \text{ MW-hrs}} = E_{II} = E_{III} = E_{IV}$

therefore when sun is shining ($t = 8-16$ hours), or $\Delta t = 8$ hours panels must collect 96 MW-hrs of energy.

We find area:

Power, P (unit area) · Area A · time, Δt :

$$PA\Delta t = 96 \text{ MW-hrs}$$ (2 pts)

$$P = \eta I_0 = 0.1(1000) = 100 \text{ W/m}^2$$

$$\therefore A = \frac{\cancel{96}\,12 \text{ MW-}\cancel{\text{hrs}}}{100 \text{ W/m}^2 \cdot \cancel{8 \text{ hrs}}} = \frac{12 \cdot 10^6 \text{ W}}{100 \text{ W/m}^2} = \underline{1.2 \times 10^5 \text{ m}^2}$$ (1 pt)

(d) Storage System Must Hold $E_{III} + E_{IV} = 48$ MW-hrs of energy (5 pts)