SOLAR PV CELLS AND SYSTEMS

Suggested Answers – NOV/DEC 2018

Question 1

(a) Define the following terms:

i. **Solar Energy:** it refers to the energy that is harvested directly from the sun using solar cells, solar concentrators, solar thermal plate etc.

ii. **Solar Altitude:** it is the angle between the sun rays and the horizontal plane. It has a symbol gamma, γ

iii. **Solar Azimuth:** it is the angle between the projection of the sun rays and the north direction. It has a symbol alpha, α

(b) State and explain four factors that affect the output (performance) of a solar PV module)

i. Temperature: as the temperature of solar cells increases, the open circuit voltage VOC decreases significantly but the short circuit current ISC increases marginally. The combined effect is a decrease of power. The output power decreases for temperatures above 25℃ and increases for temperatures below 25℃.

ii. Irradiance: As the irradiance varies there is an almost linear (but significant) variation of the short circuit current. The open circuit voltage increases slightly with higher irradiance and vice versa.

iii. Don't know yet may be geometric effects will be included

iv. And here to

(c) Kumasi is 10º N. Calculate the altitude of the sun when it is over the two tropics and the equator. (clue: +/ - 23.45º)

Solution

The formula for calculating the altitude (γ_e) of the sun when it is over the two tropics and the equator are as follows:

Equator (March 21st and September 23rd)

$$\gamma_e = 90° - \text{latitude (in degrees)} = 90° - 10° = 80°$$

Tropic of Cancer (June 22nd)

$$\gamma_e = 90° - \text{latitude (in degrees)} + 23.45° = 90° - 10° + 23.45° = 103.45°$$

Tropic of Capricorn (December 22nd)

$$\gamma_e = 90° - \text{latitude (in degrees)} - 23.45° = 90° - 10° - 23.45° = 56.55°$$

(d) Is a table calculation..

(e) A solar cell has a surface area of 50 cm^2. It is receiving irradiance of 1000 W/ m^2. Assume monochromatic light of wavelength 900 nm and a reflection coefficient of 0.9, how many photons per second reach the solar cell? If all the available photons are absorbed, what is the maximum photocurrent the cell can produce? Taking Speed of light (C) = 3.0×10^8 m/s, Planck's constant = 6.625×10^{-34} Js, Electron charge = 1.602×10^{-19} C, Energy of Photon = hf.

Solution

Frequency of incident light, $f = \frac{C}{\lambda} = \frac{3.0 \times 10^{8}}{900 \times 10^{-9}} = \mathbf{3.33 \times 10^{14} Hz}$

Energy of a single photon, $E = hf = 6.625 \times 10^{-34} \times 3.33 \times 10^{14} = \mathbf{2.208 \times 10^{-19} J}$

Available of a single photons to be absorbed by a cell;

power incident on a cell = Irradiance × Area

$= 1000\ W/m^2 \times 0.005\ m^2$

$= \mathbf{5\ J/s}$

$\text{Area} = \frac{50cm^2}{10{,}000} = 0.005m^2$

Photons reaching cell per second $= \frac{\text{power incident on a cell}}{\text{Energy of photon}}$

$= \frac{5J/s}{2.208 \times 10^{-19} J}$

$= \mathbf{2.208 \times 10^{19}\ /s}$

Considering the reflection co-efficient,

Photons likely to be absorbed $= 2.208 \times 10^{-19}\ /s \times 0.9$

$= \mathbf{1.988 \times 10^{19}\ /s}$

The maximum photocurrent the cell can produce = electron charge × no. of photons absorbed

$= 1.602 \times 10^{-19}\ C \times 1.998 \times 10^{19}\ /s$

$= \mathbf{3.201\ A}$

Question 2

(a) Define the following terms used in solar industry:

i. **Etching:** it is a process whereby wafers are polished to remove saw marks.

ii. **Screen Printing:** ….

iii. **Balance of System** …… interesting

(b) State the purpose of the Bypass Diodes and Blocking Diodes.

Bypass diodes are implemented to reduce the effects of cell mismatch on a string. They switch out a part of the string if it is driven into reverse bias.

Blocking Diodes they are also known as series diodes. They prevent current from flowing backwards through the module at night and prevent current flowing into a fault parallel string.

(c) State five inspections an Engineer/ technician should carry out on Solar PV prior to maintenance.

i. Ensure roof penetrations are watertight, if applicable
ii. Check for vegetation growth or other new shade items such as satellite dish
iii. Confirm appropriate expansion joints are used where needed in long conduits ruins.
iv. Confirm electrical enclosures are only accessible to authorised personnel, are secured with good locks.
v. Check for loose hanging wires in the array.
vi. Check for corrosion on the outside of enclosures and the racking system.
vii. Check for animal infestation under the array.

(d) Differentiate between the main types of batteries

There are two types of batteries commonly used in PV systems are: **Lead - acid batteries** and **alkaline batteries.**

Question 3

(a) Define the following terms used in solar industry:

i. **Equalisation –**

ii. **Gassing -**