Renewable Energy Technology
Mid Term Assignment
Spring 20-21

Last date of submission: 13.03.21

1. When installing a fixed flat-panel collector on a roof in Sylhet city (24.8949° N, 91.8687° E), what orientation (azimuth and tilt) should be chosen to maximize the total energy harnessed over the year?

2. Calculate the maximum and minimum solar elevation angles for Dhaka (23.8103° N, 90.4125° E).

3. What is the angle of incident of solar radiation on a horizontal surface at solar noon in Khulna city (22.8456° N, 89.5403° E) on the **A**th of July?

A should be the first 2 digits of your ID. (eg. if your ID is 18-78253-2 then A = 18)

4. What is the local solar time when it is 10h00 on the clock in Liverpool (53°N, 3°W)? Liverpool uses Greenwich Mean Time with the standard time zone meridian at 0°W. Daylight saving time is not in effect in winter.

Here, Gregorian Calendar Day (n) should be the last 2 digits of your ID. (eg. if your ID is 18-78253-2 then n = 32)

5. Calculate the position (azimuth, elevation) of the Sun at 15h30 on the clock in Istanbul (41°N,28°E). Istanbul uses Eastern European Time, with the standard time zone meridian at 30°E. Daylight saving time is in effect (summer time is one hour ahead of winter time).

Here, Gregorian Calendar Day (n) should be the last 2 digits of your ID. (eg. if your ID is 18-78253-2 then n = 32)

6. If the dark saturation current of a solar cell is 1.7×10-8A/m^2, the cell temperature is 27°C, the short-circuit current density is 250A/m^2, and the voltage at maximum power is 0.47V, calculate the open circuit voltage, Voc; current density at maximum power, Imax; maximum power, Pmax; and maximum efficiency, η_{max}. What cell area is required to get an output of 20 W when the available solar radiation is 820 W/m^2?

Ans to the Q. NO-1:

For absorbing the maximum energy it should be non tracking all over the year. As it's located in north hemisphere, it should be faced to south hemisphere. So azimuthal angle is zero. Here, it is a flate plate collector. So optimum tilt angle is equal to latitude of the location.

$$\beta_c = \phi = 24.8949^\circ$$

Ans to the Q.NO-2:

For maximum solar elevation angle (θ_s):

We know that,

Long day at dhaka = 21 June

$\therefore n$ = 21 June

= 31 + 28 + 31 + 30 + 31 + 21

= 172

Here $\phi = 23.8103$

$$\omega = \frac{\pi}{12}(t_s - 12$$

$$= \frac{\pi}{12}(12 - 12$$

$$\delta = \sin^{-1}\left[0.39795 \cos\left(2\pi \frac{172 - 173}{369}\right)\right]$$

$$= 23.44^\circ$$

$$\theta_z = \cos^{-1}(\cos\phi\cos\delta\cos\omega + \sin\alpha\sin\delta)$$

$$= \cos^{-1}[\cos(23.8103)\cos(23.44)\cos 0 + \sin(23.8103)\sin(23.44]$$

$$= 0.3703^\circ$$

Now,
$\theta_s = 90 - 0.7$
$= 89.629°$

For minimum solar elevation (θ_{s1}):
21th december is short day
so, n = 21th december
$= 365 - 10$
$= 355.$

$\omega = \frac{\pi}{12}(t_s - 12)$
$= 0 \quad [\because t_s = 012]$

$\delta = \sin^{-1}[0.39795 \cos(2\pi \frac{355 - 173}{365})]$
$= -23.44°$

$\theta_T = \cos^{-1}[\cos(23.8103)\cos(-23.44)\cos 0 - \sin(23.8103)\sin(-23.44)]$
$= 47.25°$

$\theta_s = \pi/2 - \theta_z$
$= 42.74°$

Ans to the Q.no - 3:

ID: 18-37400-1

Here, A = 18

Hour angle,
$\omega = \frac{\pi}{12}(t_s - 12)$
$= \frac{\pi}{12}(12 - 12)$
$= 0$

Horizontal Surface, $\beta_c = 0$

Now, Angle of incident of solar radiation-
$\theta = \cos^{-1}[\cos\beta_c \cos\theta_z + \sin\beta_z \sin\theta_z \cos(\pi_s - \pi_c)]$

$\Rightarrow \theta = \cos^{-1}[\cos\theta_1 + \sin 0° \sin\theta_2 \cos(\pi_s - \pi_e)]$

$\Rightarrow \theta = \cos^{-1}(\cos\theta_2 + 0)$

$\Rightarrow \theta = \theta_2$

For Khulna latitude, $\phi = 22.8456°$

$n = 4$th July

$= 18$th July

$= 31 + 28 + 31 + 30 + 31 + 30 + 18$

$= 199$

$\delta = \sin^{-1}\left(0.39795 \cos\left(2\pi \frac{n-173}{365}\right)\right)$

$= 21.02°$

$\theta_z = \cos^{-1}[\cos(22.8456)\cos(21.02)\cos 0 + \sin(22.8$

$= 1.825°$ $\sin(21.02)]$

The angle of incident of solar radiation is

$\theta = \theta_z = \theta_7 = 1.825°$

Ans to the question No. 9

ID: 18-37400-1

n: 01 = 1

t_{clk} = 10 hour

ψ_{std} = 0

ψ_{loc} = 3°

Δt_{DST} = 0

A = 0.258

B = -7.416

C = -3.648

D = -9.228

Now,

$$\Delta t_{EOT} = A\cos\left(2\pi\frac{n-1}{365}\right) + B\sin\left(2\pi\frac{n-1}{365}\right) + C\cos\left(4\pi\frac{n-1}{365}\right) + D\sin\left(4\pi\frac{n}{3}\right.$$

$$= -3.39$$

$$t_s = t_{clk} + \frac{\psi_{std} - \psi_{loc}}{15^\circ} + \frac{\Delta t_{EOT}}{60} + \Delta t_{DST}$$

$$= 10 + \frac{0-3}{15} + \frac{-3.39}{60} + 0$$

$$= 9.74 \text{ hour}$$

Solar time t_s = 9.74 hour

Ans to the question No. 5

ID : 18-37400-1

$n = 1$

$t_{clk} = 15.5$ hour

$\phi = 41^\circ$

$\psi_{loc} = 28$ $\quad \psi_{std} = 30^\circ$

$\Delta t_{DST} = 1$

$$\Delta t_{EOT} = A\cos\left(2\pi \frac{n-1}{365}\right) + B\sin\left(2\pi \frac{n-1}{365}\right) + C\cos\left(4\pi \frac{n-1}{365}\right) + D\sin\left(4\pi \frac{n-1}{365}\right)$$

$$= -3.39$$

$$t_s = 15.5 + \frac{30-28}{15} + \frac{-3.39}{60} + 1 = 16.57 \text{ hour}$$

$$\omega = \frac{\pi}{12}(t_s - 12)$$

$$= \frac{\pi}{12}(16.57 - 12) = 68.55^\circ$$

$$\delta = \sin^{-1}\left(0.39795\cos\left(2\pi \frac{n-173}{365}\right)\right) = -23.04^\circ$$

$$\theta_z = \cos^{-1}\left[\cos(41)\cos(-23.04)\cos(68.55) + \sin(41)\sin(-23.04)\right]$$

$$= 90.15^\circ$$

$\theta_s = \frac{\pi}{2} - \theta_2 = -0.159$

$\gamma_s = \text{sgn}(\omega) \cos^{-1}\left[\frac{\cos\theta_2 \sin\phi - \sin\delta}{\sin\theta_2 \cos\phi}\right]$ $\quad \text{sgn}(\cos 55) = +1$

$= 58.91^\circ$

Azimuth angle = 58.91°

Elevation angle = -0.159°

Ans to the Q. No -6:

Here,

$I_o = 1.7 \times 10^{-8} A/m^2$

$I_{sc} = 250\ Am^{-1}$ $\quad T_e = 27°c$

$V_m = 0.47V$ $\quad = 300K$

We know that,

$$\frac{e}{KT_e} = \frac{1.602 \times 10^{-19}}{1.381 \times 10^{-23} \times 300}$$

$$= 38.67$$

$$I_{max} = \frac{e V_m}{KT_e + eV_m} (I_{sc} + I_o)$$

$$= \frac{(1.602 \times 10^{-15} \times 0.47)(250 + 1.7 \times 10^{-8})}{(1.381 \times 10^{-23} \times 300) + (1.602 \times 10^{-19} \times 0.47)}$$

$$= 236.97\ Am^{-2}$$

$$V_{AC} = \frac{KT_e}{e} \ln\left(\frac{I_{sc}}{I_o} + 1\right)$$

$$= \frac{1.38 \times 10^{-23} \times 300}{1.602 \times 10^{-19}} \times \ln\left(\frac{250}{1.7 \times 10^{-8}} + 1\right)$$

$$= 0.605V$$

$$P_{max} = V_m I_m$$

$$= 0.47 \times 236.96$$

$$= 111.37\ W$$

$$\eta_{max} = \frac{111.37}{820} \times 100$$

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$$= 13.587$$

$$A = \frac{20}{111.37} = 0.179$$