EECE325 Fundamentals of Energy Systems
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Spring 2022

Homework 6 (100 points)

A. INSTRUCTION

Apply the clear-sky insolation equations as provided in the accompanying handout, and answers the 3 questions in the B. PROBLEM.
(a) Due: 8:00pm Wed Apr 13
(b) Scoring Rubric

pts	Q1, Q2, and Q3
33	Correct answers for (b) 10 am and (c) 2pm calculations with sufficient works displayed.
20	Incorrect answers for (b) 10 am and (c) 2pm calculations with sufficient works displayed.
10	Correct answers for (b) 10 am and (c) 2pm calculations without sufficient works displayed.
0	Incorrect answer without work displayed

(c) Submission extension: granted upon request

B. PROBLEM

Question 1: Calculate the clear sky insolation on a fixed titled angle of 40° facing south collector located at 40° latitude at (a) solar noon, (b) at 10:00am, and (c) 2:00pm on the summer solstice. Ignore the reflected insolation.

Question 2: Calculate the clear sky insolation on a single-axis polar mount collector located at 40° latitude at (a) solar noon , (b) at 10:00am, and (c) 2:00pm on the summer solstice. Ignore the reflected insolation.

Question 3: Calculate the clear sky insolation on a two-axis tracking collector located at 40° latitude at (a) solar noon, (b) at 10:00am, and (c) 2:00pm on the summer solstice. Ignore the reflected insolation.

*** See the next page for clear-sky insolation equations**

Summary of Clear-Sky Solar Insolation Equations

I_0 = extraterrestrial solar insolation
m = air mass ratio
I_B = beam insolation at earth's surface
A = apparent extraterrestrial solar insolation
k = atmospheric optical depth
C = sky diffuse factor
I_{BC} = beam insolation on collector
θ = incidence angle
Σ = collector tilt angle
I_H = insolation on a horizontal surface
I_{DH} = diffuse insolation on a horizontal surface
I_{DC} = diffuse insolation on collector
I_{RC} = reflected insolation on collector
ρ = ground reflectance
I_C = insolation on collector
n = day number
β = solar altitude angle
δ = solar declination
ϕ_S = solar azimuth angle (+ = AM)
ϕ_C = collector azimuth angle (+ = SE)

$$I_0 = 1370\left[1 + 0.034\cos\left(\frac{360n}{365}\right)\right] \text{(W/m}^2\text{)}$$

$$m = \frac{1}{\sin\beta}$$

$$I_B = Ae^{-km}$$

$$A = 1160 + 75\sin\left[\frac{360}{365}(n - 275)\right] \text{(W/m}^2\text{)}$$

$$k = 0.174 + 0.035\sin\left[\frac{360}{365}(n - 100)\right]$$

$$I_{BC} = I_B\cos\theta$$

$$\cos\theta = \cos\beta\cos(\phi_S - \phi_C)\sin\Sigma + \sin\beta\cos\Sigma$$

$$I_{BH} = I_B\cos(90^\circ - \beta) = I_B\sin\beta$$

$$I_{DH} = CI_B$$

$$C = 0.095 + 0.04\sin\left[\frac{360}{365}(n - 100)\right]$$

$$I_{DC} = I_{DH}\left(\frac{1 + \cos\Sigma}{2}\right) = I_B C\left(\frac{1 + \cos\Sigma}{2}\right)$$

$$I_{RC} = \rho I_B(\sin\beta + C)\left(\frac{1 - \cos\Sigma}{2}\right)$$

$$I_C = I_{BC} + I_{DC} + I_{RC}$$

$$I_C = Ae^{-km}\left[\cos\beta\cos(\phi_S - \phi_C)\sin\Sigma + \sin\beta\cos\Sigma + C\left(\frac{1 + \cos\Sigma}{2}\right) + \rho(\sin\beta + C)\left(\frac{1 - \cos\Sigma}{2}\right)\right]$$

$$\sin\beta = \cos L\cos\delta\cos H + \sin L\sin\delta$$

$$\sin\phi_S = \frac{\cos\delta\sin H}{\cos\beta}$$

$$\text{Hour angle } H = \left(\frac{15^\circ}{\text{hour}}\right)\cdot\text{(hours before solar noon)}$$

Two-Axis Tracking:

$$I_{BC} = I_B$$

$$I_{DC} = CI_B\left[\frac{1 + \cos(90^\circ - \beta)}{2}\right]$$

$$I_{RC} = \rho(I_{BH} + I_{DH})\left[\frac{1 - \cos(90^\circ - \beta)}{2}\right]$$

One-Axis, Polar Mount:

$$I_{BC} = I_B\cos\delta$$

$$I_{DC} = CI_B\left[\frac{1 + \cos(90^\circ - \beta + \delta)}{2}\right]$$

$$I_{RC} = \rho(I_{BH} + I_{DH})\left[\frac{1 - \cos(90^\circ - \beta + \delta)}{2}\right]$$