

Renewable and Efficient Electric Power Systems (2nd Edition)

Chapter 4, Problem 11P

Bookmark

Show all steps:

ON

Step-by-step solution

Step 1 of 40

(a)

Consider the solar declination formula.

$$\delta = 23.45 \sin \left[\frac{360}{365} (n - 100) \right] \dots\dots (1)$$

Where,

δ is the solar declination,

n is the solar number.

Substitute 182 for n in Equation (1)

$$\delta = 23.45 \sin \left[\frac{360}{365} (182 - 100) \right]$$
$$= 23.45 \sin \left[\frac{360}{365} (182 - 100) \right]$$
$$= 23.12^\circ$$

Comment

Step 2 of 40

Consider the altitude angle of the sun at zero degree.

The altitude angle is defined as angle between the sun and local horizontal directly beneath the sun.

$$\beta = 90^\circ - L + \delta \dots\dots (2)$$

Where,

β is the altitude angle in degree,

L is the local altitude in degree,

δ is the solar declination in degree.

Substitute 39.8 for L and 23.12 for δ in Equation (2).

$$\beta = 90^\circ - L + \delta$$
$$= 90^\circ - 39.8^\circ + 23.12^\circ$$
$$= 73.32^\circ$$

Comment

Step 3 of 40

Consider the formula for incidence angle.

$$\cos \theta = \cos \beta \cos (\phi_s - \phi_c) \sin \Sigma + \sin \beta \cos \Sigma \dots\dots (3)$$

Where,

ϕ_s is the solar azimuth angle,

ϕ_c is the collector azimuth angle,

Σ is the solar collector tipped up at an angle.

Substitute 40 for Σ , 0 for ϕ_s & ϕ_c and 73.32 for β in Equation (3).

$$\cos \theta = \cos \beta \cos (\phi_s - \phi_c) \sin \Sigma + \sin \beta \cos \Sigma$$
$$= \cos 73.32^\circ \cos (0 - 0) \sin 40^\circ + \sin 73.32^\circ \cos 40^\circ$$
$$= 0.9183$$

Comment

Step 4 of 40

Consider the formula for beam isolation striking a collector face.

$$I_{BC} = I_{DNI} \cos \theta \dots\dots (4)$$

Where,

I_{BC} is the beam isolation striking a collector face,

I_{DNI} is the beam isolation on the earth surface.

Substitute 901 for I_{DNI} and 0.9183 for $\cos \theta$ in Equation (4).

$$I_{BC} = I_{DNI} \cos \theta$$
$$= 901 \times 0.9183$$
$$= 827.4 \text{ W/m}^2$$

Comment

Step 5 of 40

Consider the formula for diffuse insolation on collector.

$$I_{DC} = I_{DNI} \left(\frac{1 + \cos \Sigma}{2} \right) \dots\dots (5)$$

Where,

I_{DC} is the diffuse insolation on collector face,

I_{DNI} is the diffuse insolation on horizontal surface.

Substitute 143 for I_{DNI} and 40 for Σ in Equation (5).

$$I_{DC} = I_{DNI} \left(\frac{1 + \cos \Sigma}{2} \right)$$
$$= 143 \times \left(\frac{1 + \cos 40}{2} \right)$$
$$= 126.3 \text{ W/m}^2$$

Comment

Step 6 of 40

Consider the formula for reflection insolation.

$$I_{RC} = \rho I_H \left(\frac{1 - \cos \Sigma}{2} \right) \dots\dots (6)$$

Where,

I_{DC} is the diffuse insolation on collector face,

I_H is the diffuse insolation on horizontal surface,

ρ is the ground reflection.

Substitute 0.2 for ρ , 998 for I_H and 40 for Σ in Equation (6).

$$I_{RC} = \rho I_H \left(\frac{1 - \cos \Sigma}{2} \right)$$
$$= 0.2 \times 998 \times \left(\frac{1 - \cos 40}{2} \right)$$
$$= 23.3 \text{ W/m}^2$$

Comment

Step 7 of 40

Consider the formula for insolation on collector.

$$I_C = I_{BC} + I_{DC} + I_{RC} \dots\dots (7)$$

Where,

I_C is the insolation on collector.

Substitute 827.4 for I_{BC} , 126.3 for I_{DC} and 23.3 for I_{RC} in Equation (7).

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 827.4 \text{ W/m}^2 + 126.3 \text{ W/m}^2 + 23.3 \text{ W/m}^2$$
$$= 977 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{977 \text{ W/m}^2}$.

Comment

Step 8 of 40

(b)

Change in tilt angle is 30 degree with reflectance is 0.2.

Substitute 300 for ρ , 0 for ϕ_s & ϕ_c and 73.32 for β in Equation (3).

$$\cos \theta = \cos \beta \cos (\phi_s - \phi_c) \sin \Sigma + \sin \beta \cos \Sigma$$
$$= \cos 73.32^\circ \cos (0 - 0) \sin 30^\circ + \sin 73.32^\circ \cos 30^\circ$$
$$= 0.9686$$

Comment

Step 9 of 40

Substitute 901 for I_{DNI} and 0.9686 for $\cos \theta$ in Equation (4).

$$I_{BC} = I_{DNI} \cos \theta$$
$$= 901 \times 0.9686$$
$$= 872.73 \text{ W/m}^2$$

Comments (1)

Step 10 of 40

Substitute 143 for I_{DNI} and 30 for Σ in Equation (5).

$$I_{DC} = I_{DNI} \left(\frac{1 + \cos \Sigma}{2} \right)$$
$$= 143 \times \left(\frac{1 + \cos 30}{2} \right)$$
$$= 133.42 \text{ W/m}^2$$

Comment

Step 11 of 40

Substitute 0.2 for ρ , 998 for I_H and 30 for Σ in Equation (6).

$$I_{RC} = \rho I_H \left(\frac{1 - \cos \Sigma}{2} \right)$$
$$= 0.2 \times 998 \times \left(\frac{1 - \cos 30}{2} \right)$$
$$= 13.37 \text{ W/m}^2$$

Comment

Step 12 of 40

Substitute 872.34 for I_{BC} , 133.42 for I_{DC} and 13.37 for I_{RC} in Equation (7).

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 872.76 \text{ W/m}^2 + 133.42 \text{ W/m}^2 + 13.37 \text{ W/m}^2$$
$$= 1,019.55 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{1,019.55 \text{ W/m}^2}$.

Comments (1)

Step 13 of 40

(c)

Consider the north-south horizontal axis tracking collector at 11:00 am solar time.

Substitute 182 for n in Equation (1).

$$\delta = 23.45 \sin \left[\frac{360}{365} (n - 100) \right]$$
$$= 23.45 \sin \left[\frac{360}{365} (182 - 100) \right]$$
$$= 23.12^\circ$$

Comment

Step 14 of 40

Consider the altitude angle of the sun at zero degree.

The altitude angle is defined as angle between the sun and local horizontal directly beneath the sun.

$$\sin \beta = \cos L \cos \delta \cos H + \sin L \sin \delta \dots\dots (8)$$

Where,

β is the altitude angle in degree,

L is the local altitude in degree,

δ is the solar declination in degree.

Substitute 39.8 for L , 15 for H and 23.12 for δ in Equation (8).

$$\sin \beta = \cos L \cos \delta \cos H + \sin L \sin \delta$$
$$= \cos 39.8^\circ \times \cos 23.12 \cos 15 + \sin 39.8^\circ \sin 23.12$$
$$= 0.8729^\circ$$
$$\beta = 69.04^\circ$$

Comments (1)

Step 15 of 40

Consider the solar azimuth angle.

$$\sin \phi_s = \frac{\cos \delta \sin H}{\cos \beta} \dots\dots (9)$$

Where,

ϕ_s is the solar azimuth angle in degree.

Comment

Step 16 of 40

Substitute 69.04 for β , 15 for H and 23.12 for δ in Equation (9).

$$\sin \phi_s = \frac{\cos \delta \sin H}{\cos \beta}$$
$$= \frac{\cos 23.12 \sin 15}{\cos 69.04}$$
$$= 0.6654$$
$$\phi_s = 41.72^\circ$$

Comment

Step 17 of 40

Consider the formula for incidence angle.

$$\cos \theta = \sqrt{1 - (\cos \beta \cos \phi_s)^2} \dots\dots (10)$$

Where,

ϕ_s is the solar azimuth angle.

Substitute 41.72 for ϕ_s and 69.04 for β in Equation (10).

$$\cos \theta = \sqrt{1 - (\cos \beta \cos \phi_s)^2}$$
$$= \sqrt{1 - (\cos 69.04 \cos 41.72)^2}$$
$$= 0.964$$

Comment

Step 18 of 40

Substitute 889 for I_{DNI} and 0.964 for $\cos \theta$ in Equation (4).

$$I_{BC} = I_{DNI} \cos \theta$$
$$= 889 \times 0.964$$
$$= 857 \text{ W/m}^2$$

Comment

Step 19 of 40

Consider the formula for diffuse insolation on collector.

$$I_{DC} = I_{DNI} \left(\frac{1 + \sin \beta / \cos \theta}{2} \right) \dots\dots (11)$$

Where,

I_{DC} is the diffuse insolation on collector face,

I_{DNI} is the diffuse insolation on horizontal surface.

Substitute 138 for I_{DNI} , 69.04 for β and 0.964 for $\cos \theta$ in Equation (11).

$$I_{DC} = I_{DNI} \left(\frac{1 + \sin \beta / \cos \theta}{2} \right)$$
$$= 138 \times \left(\frac{1 + \sin 69.04 / 0.964}{2} \right)$$
$$= 136 \text{ W/m}^2$$

Comment

Step 20 of 40

Consider the formula for reflection insolation.

$$I_{RC} = \rho I_H \left(\frac{1 - \sin \beta / \cos \theta}{2} \right) \dots\dots (12)$$

Where,

I_{DC} is the diffuse insolation on collector face,

I_H is the diffuse insolation on horizontal surface,

ρ is the ground reflection.

Substitute 0.2 for ρ , 938 for I_H , 69.04 for β and 0.964 for $\cos \theta$ in Equation (12).

$$I_{RC} = \rho I_H \left(\frac{1 - \sin \beta / \cos \theta}{2} \right)$$
$$= 0.2 \times 938 \times \left(\frac{1 - \sin 69.04 / 0.964}{2} \right)$$
$$= 3 \text{ W/m}^2$$

Comment

Step 21 of 40

Substitute 857 for I_{BC} , 136 for I_{DC} and 3 for I_{RC} in Equation (7).

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 857 \text{ W/m}^2 + 136 \text{ W/m}^2 + 3 \text{ W/m}^2$$
$$= 996 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{996 \text{ W/m}^2}$.

Comment

Step 22 of 40

(d)

Consider the solar noon at 12:00pm refer the Table P4.11 in text book.

Substitute 901 for I_{DNI} and 0.964 for $\cos \theta$ in Equation (4).

$$I_{BC} = I_{DNI} \cos \theta$$
$$= 901 \times 0.964$$
$$= 868.564 \text{ W/m}^2$$

Comment

Step 23 of 40

Substitute 143 for I_{DNI} , 69.04 for β and 0.964 for $\cos \theta$ in Equation (11).

$$I_{DC} = I_{DNI} \left(\frac{1 + \sin \beta / \cos \theta}{2} \right)$$
$$= 143 \times \left(\frac{1 + \sin 69.04 / 0.964}{2} \right)$$
$$= 140.76 \text{ W/m}^2$$

Comment

Step 24 of 40

Substitute 0.2 for ρ , 998 for I_H , 69.04 for β and 0.964 for $\cos \theta$ in Equation (12).

$$I_{RC} = \rho I_H \left(\frac{1 - \sin \beta / \cos \theta}{2} \right)$$
$$= 0.2 \times 998 \times \left(\frac{1 - \sin 69.04 / 0.964}{2} \right)$$
$$= 3.12 \text{ W/m}^2$$

Comment

Step 25 of 40

Post a question

Answers from our experts for your tough homework questions.

Enter question

Continue to post

Continue to edit and attach image(s).

My Textbook Solutions

Renewable and...



Renewable and Efficient Electric Power Systems

Electrical Control for...

Solid Waste Engineering

6th Edition

2nd Edition

View all solutions

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 868.58 \text{ W/m}^2 + 140.76 \text{ W/m}^2 + 3.12 \text{ W/m}^2$$
$$= 1,012.46 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{1,012.46 \text{ W/m}^2}$.

[Comment](#)

Step 26 of 40

(e)

Consider the two axis tracker at reflectance is 0.2.

Substitute 901 for I_{DNI} and 1 for $\cos \theta$ in Equation (4).

$$I_{RC} = I_{DNI} \cos \theta$$
$$= 901 \times 1$$
$$= 901 \text{ W/m}^2$$

[Comment](#)

Step 27 of 40

Consider the formula for diffuse insolation on collector.

$$I_{DC} = I_{DNI} \left(\frac{1 + \sin \beta}{2} \right) \dots\dots (13)$$

Where,

I_{DC} is the diffuse insolation on collector face,

I_{DNI} is the diffuse insolation on horizontal surface.

Substitute 143 for I_{DNI} and 73.32 for β in Equation (13).

$$I_{DC} = I_{DNI} \left(\frac{1 + \sin \beta}{2} \right)$$
$$= 143 \times \left(\frac{1 + \sin 73.32}{2} \right)$$
$$= 140 \text{ W/m}^2$$

[Comment](#)

Step 28 of 40

Consider the formula for reflection insolation.

$$I_{RC} = \rho I_{DNI} \left(\frac{1 - \sin \beta}{2} \right) \dots\dots (14)$$

Where,

I_{DC} is the diffuse insolation on collector face,

I_{DNI} is the diffuse insolation on horizontal surface,

ρ is the ground reflection.

Substitute 0.2 for ρ , 998 for I_{DNI} and 73.32 for β in Equation (14).

$$I_{RC} = \rho I_{DNI} \left(\frac{1 - \sin \beta}{2} \right)$$
$$= 0.2 \times 998 \times \left(\frac{1 - \sin 73.32}{2} \right)$$
$$= 4 \text{ W/m}^2$$

[Comments \(1\)](#)

Step 29 of 40

Substitute 901 for I_{BC} , 140 for I_{DC} and 4 for I_{RC} in Equation (7).

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 901 \text{ W/m}^2 + 140 \text{ W/m}^2 + 4 \text{ W/m}^2$$
$$= 1,045 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{1,045 \text{ W/m}^2}$.

[Comment](#)

Step 30 of 40

(f)

Consider the two axis tracker for 11:00 am.

Substitute 138 for I_{DNI} and 73.32 for β in Equation (13).

$$I_{DC} = I_{DNI} \left(\frac{1 + \sin \beta}{2} \right)$$
$$= 138 \times \left(\frac{1 + \sin 73.32}{2} \right)$$
$$= 135.09 \text{ W/m}^2$$

[Comment](#)

Step 31 of 40

Substitute 0.2 for ρ , 938 for I_{DNI} and 73.32 for β in Equation (14).

$$I_{RC} = \rho I_{DNI} \left(\frac{1 - \sin \beta}{2} \right)$$
$$= 0.2 \times 938 \times \left(\frac{1 - \sin 73.32}{2} \right)$$
$$= 3.94 \text{ W/m}^2$$

[Comment](#)

Step 32 of 40

Substitute 901 for I_{BC} , 135.09 for I_{DC} and 3.94 for I_{RC} in Equation (7).

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 901 \text{ W/m}^2 + 135.09 \text{ W/m}^2 + 3.94 \text{ W/m}^2$$
$$= 1,040.00 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{1,040 \text{ W/m}^2}$.

[Comment](#)

Step 33 of 40

(g)

For one axis tracker at reflectance is 0.2.

Consider the formula for beam isolation striking a collector face.

$$I_{BC} = I_{DNI} \sin (\beta + \Sigma) \dots\dots (15)$$

Where,

I_{BC} is the beam isolation striking a collector face,

I_{DNI} is the beam isolation on the earth surface.

Substitute 901 for I_{DNI} , 30 for Σ and 73.32 for β in Equation (15).

$$I_{BC} = I_{DNI} \sin (\beta + \Sigma)$$
$$= 901 \times \sin (73.32 + 30)$$
$$= 876.7 \text{ W/m}^2$$

[Comment](#)

Step 34 of 40

Consider the formula for diffuse insolation on collector.

$$I_{DC} = I_{DNI} \left(\frac{1 + \cos \Sigma}{2} \right) \dots\dots (16)$$

Where,

I_{DC} is the diffuse insolation on collector face,

I_{DNI} is the diffuse insolation on horizontal surface.

Substitute 138 for I_{DNI} and 30 for Σ in Equation (16).

$$I_{DC} = I_{DNI} \left(\frac{1 + \cos \Sigma}{2} \right)$$
$$= 138 \times \left(\frac{1 + \cos 30}{2} \right)$$
$$= 128.75 \text{ W/m}^2$$

[Comment](#)

Step 35 of 40

Consider the formula for reflection insolation.

$$I_{RC} = \rho I_{DNI} \left(\frac{1 - \cos \Sigma}{2} \right) \dots\dots (17)$$

Where,

I_{DC} is the diffuse insolation on collector face.

I_{DNI} is the diffuse insolation on horizontal surface,

ρ is the ground reflection.

Substitute 0.2 for ρ , 938 for I_{DNI} and 30 for Σ in Equation (17).

$$I_{RC} = \rho I_{DNI} \left(\frac{1 - \cos \Sigma}{2} \right)$$
$$= 0.2 \times 938 \times \left(\frac{1 - \cos 30}{2} \right)$$
$$= 12.56 \text{ W/m}^2$$

[Comment](#)

Step 36 of 40

Substitute 876.1 for I_{BC} , 128.75 for I_{DC} and 12.56 for I_{RC} in Equation (7).

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 876.1 \text{ W/m}^2 + 128.75 \text{ W/m}^2 + 12.56 \text{ W/m}^2$$
$$= 1,018 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{1,018 \text{ W/m}^2}$.

[Comment](#)

Step 37 of 40

(h)

For one axis tracker at reflectance is 0.2 for solar noon.

Consider the formula for beam isolation striking a collector face.

$$I_{BC} = I_{DNI} \sin (\beta + \Sigma) \dots\dots (15)$$

Where,

I_{BC} is the beam isolation striking a collector face,

I_{DNI} is the beam isolation on the earth surface.

Substitute 901 for I_{DNI} , 30 for Σ and 73.32 for β in Equation (15).

$$I_{BC} = I_{DNI} \sin (\beta + \Sigma)$$
$$= 901 \times \sin (73.32 + 30)$$
$$= 876.7 \text{ W/m}^2$$

[Comment](#)

Step 38 of 40

Substitute 138 for I_{DNI} and 30 for Σ in Equation (16).

$$I_{DC} = I_{DNI} \left(\frac{1 + \cos \Sigma}{2} \right)$$
$$= 143 \times \left(\frac{1 + \cos 30}{2} \right)$$
$$= 133.4 \text{ W/m}^2$$

[Comment](#)

Step 39 of 40

Substitute 0.2 for ρ , 998 for I_{DNI} and 30 for Σ in Equation (17).

$$I_{RC} = \rho I_{DNI} \left(\frac{1 - \cos \Sigma}{2} \right)$$
$$= 0.2 \times 998 \times \left(\frac{1 - \cos 30}{2} \right)$$
$$= 13.4 \text{ W/m}^2$$

[Comment](#)

Step 40 of 40

Substitute 876.1 for I_{BC} , 133.4 for I_{DC} and 13.4 for I_{RC} in Equation (7).

$$I_C = I_{BC} + I_{DC} + I_{RC}$$
$$= 876.1 \text{ W/m}^2 + 133.4 \text{ W/m}^2 + 13.4 \text{ W/m}^2$$
$$= 1,024 \text{ W/m}^2$$

Thus, the insolation for collector face is $\boxed{1,024 \text{ W/m}^2}$.

[Comment](#)

Was this solution helpful? ☐ 3 ☐ 0

Recommended solutions for you in Chapter 4

- Become a Tutor

Chegg For Good

College Marketing

Corporate Development

Investor Relations

Jobs

Join Our Affiliate Program

Media Center

Site Map
- Advertising Choices

Cookie Notice

General Policies **Updated**

Intellectual Property Rights

International Privacy Policy

Terms of Use **Updated**

Chegg Tutors Terms of Service

US Privacy Policy

Your CA Privacy Rights
- Cheap Textbooks

Chegg Coupon

Chegg Play

Chegg Study Help

College Textbooks

eTextbooks

Chegg Math Solver

Mobile Apps
- Online Tutoring

Sell Textbooks

Solutions Manual

Study 101

Test Prep

Textbook Rental

Used Textbooks

Digital Access Codes
- CareerMatch

EasyBib

Internships.com

Studyblue
- Customer Service

Give Us Feedback

Help with Chegg Tutors

Help with eTextbooks

Help to use EasyBib Plus

Manage Chegg Study Subscription

Return Your Books

Textbook Return Policy

