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Calculation of the Shading in the PV-Generators Design

Many solar collection devices are fixed or move with only limited freedom. As a result the collection apertures do not face directly toward the sun at all times. Therefore the photovoltaic (PV) generators have to be able to collect as more solar energy as possible.The magnitude of the beam component of direct normal radiation is therefore insufficient information to estimate the energy intercepted by solar collector surface. In this paper the virtual motion of the sun is given and the calculation of the shading is also described.

1. Introduction

The earth spins daily on an imaginary axis orientated in a fixed direction relative to the plane of the earth's yearly orbit about the sun.The angle this direction makes with the orbital plane is the solar declination (23.45º).

This apparent motion is indicated in Fig.1 for an observer at latitude 42º north (the latitude of Bulgaria). On any given day, the plane of the sun's apperant orbit lies at an angle equal to the latitude from the observer's vertical. At the equinoxes (March 21 and Serptember 23), the sun rises due east and sets due west, so that the altitude of the sun at solar noon on these days equals 90º minus the latitude. At the summer and winter soltices (June 21 and December 22, respectively, for the northern hemisphere, the opposite for the southern), the altitude at solar noon has increased by the declination of the earth (23.45º).

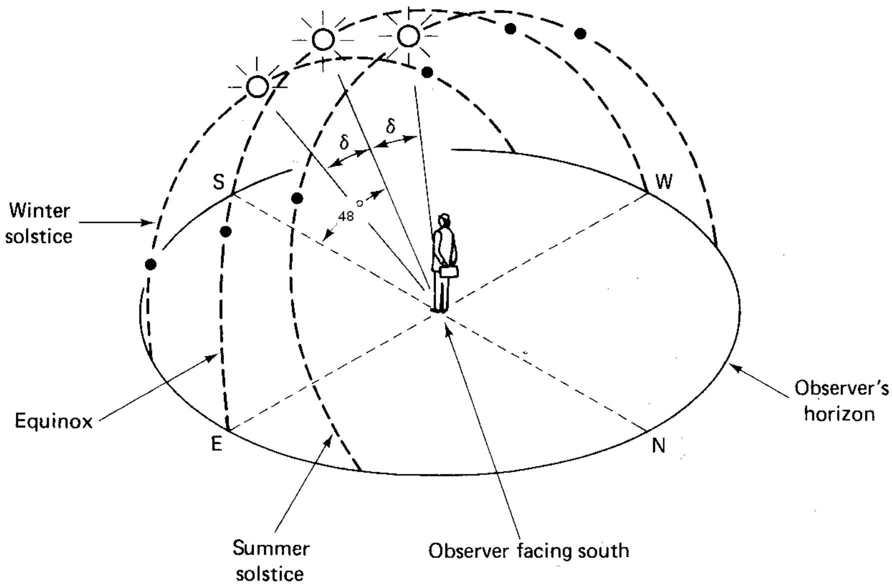

Figure 1. Apparent motion of the sun relative to a fixed observer at latitude 420 in the northern hemisphere. The path of the sun is shown at the equinoxes and the summer and winter solstices. The position of the sun is shown at solar noon on each of these days. The shaded circles represent the sun's position 3 h before and after solar noon.

2. Evaluating The Distance Between The Modules

The distance between two neighbour modules (rows of modules) is evaluated as follows:

$$D = \frac{\sin\alpha\ .L}{\tan\beta} \qquad (1)$$

where:

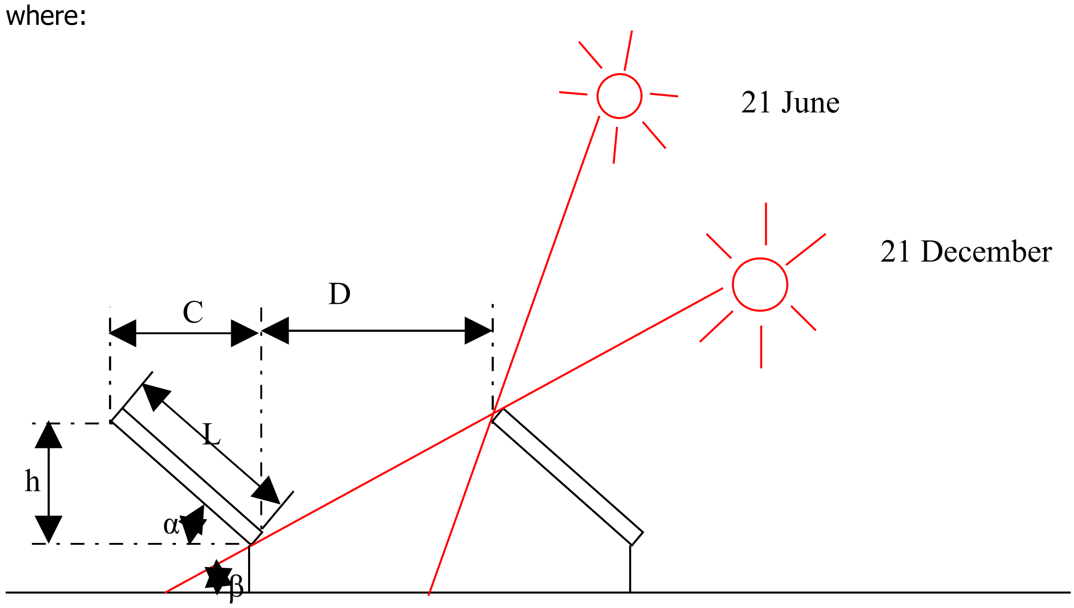

Figure 2. Sun path and distance evaluation.

h = sinα.L
C = cosα.L
D_{ij} – distance between i-th and j-th row
α – modules tilt
L – length of the module
β – noon altitude of the sun

$$\beta = 90 - \Phi \pm \delta \qquad (2)$$

Φ – latitude (equal to 42º for Bulgaria)
δ= + 23.45^0 – in the summer (June 21)
δ= - 23.45^0 – in the winter (December 22)

We use the smaller value of β to avoid shading и the winter.

The plus sign in equation 2. applies for the northern hemisphere, the negative for the southern. Here Φ is the latitude and β the declination of the sun, given by

$$\delta = 23.45^o \sin\left[\frac{360}{365}(d - 81)\right] \quad (3)$$

where d is the number of days from the beginning of the year.
assume β=19°

3. Example

This methodology has been used for evaluating the distance between the rows of 10kWp Photovoltaic system designed in Technical University of Gabrovo, Bulgaria.

The system consists of 120 modules in 3 rows (two sub-systems), mounted at fixed angle of 33^0.

Sub-system II. – Modules type ASE – F 32/12

The input date is as follows:
length of the first row – 20,29m
width of the first row L – 3,065m
tilt angle of the row - 330

1-st row: α = 33º; 20 modules x 1.005m = 20.1m+0.19m (1cm distance between every two modules) =20.29m;
L1=5x0.605m=3.025m + 0.04m(1cm distance between every two modules) =3.065m
C1=2.57m
h1=1.67m

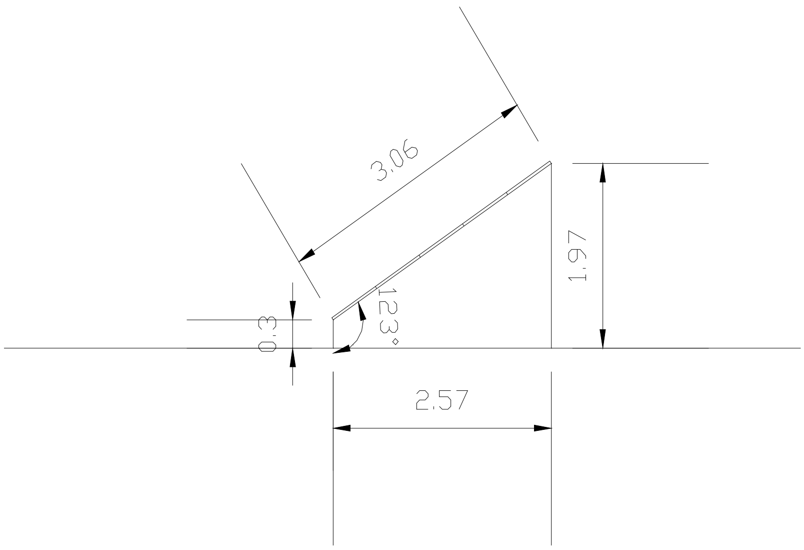

Figure 3. Sizing of the first row.

Sub-system I. – Modules type ASE – 250 DG – FT/MC

The input date is as follows:
length of the second row – 9,68m
width of the first row L –2,68m
tilt angle of the row - 330

2-nd row: ɑ = 33º; 6 modules x 1.605m = 9.63m+0.05m (1cm distance between every two modules)=9.68m;
L3=2x1.336m=2.67m + 0.01m(1cm distance between every two modules) =2.68m
C3=2.25m
h3=1.46m
D12=4.85 x 1.1=5.34m

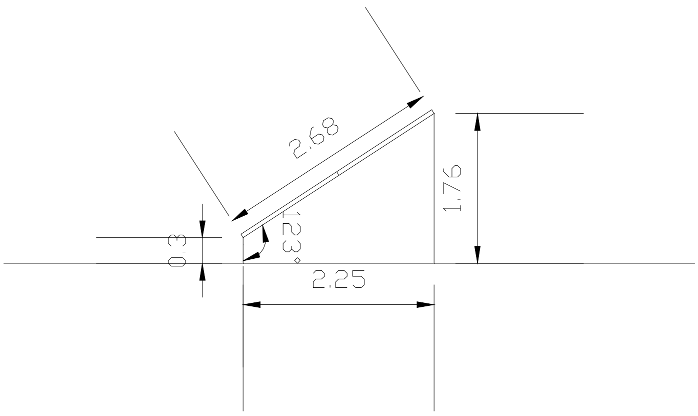

Figure 4. Sizing of the second row.

The input date is as follows:
length of the third row – 9,68m
width of the third row L –2,68m
tilt angle of the row - 330
3-rd row: α = 30º; 6 modules x 1.605m = 9.63m+0.05m(1cm distance between every two modules)=9.68m;
L4=2x1.336m=2.67m+ 0.01m(1cm distance between every two modules) =2.68m
C3=2.25m
h3=1.46m
D12=3.31 x 1.1=4.66m

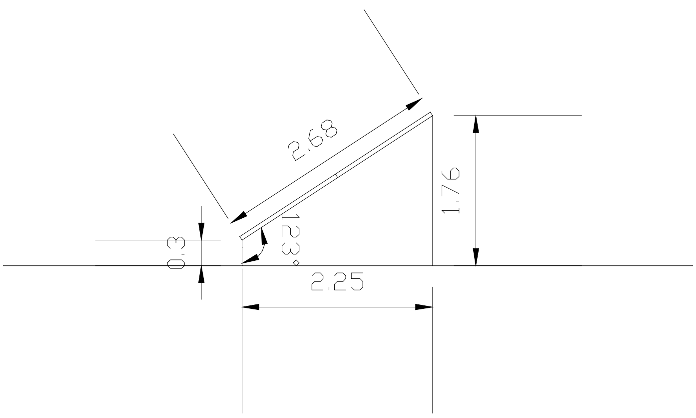

Figure 5. Sizing of the third row.

4. Conclusion

The distance evaluation is an important part of the PV system design in order to avoid, not only additional power loses, but also damages of the modules because of the shading effect. An important point of this study is the proper evaluation of the altitude of the sun at solar noon according to the local conditions (latitude of the country).

The proposed methodology is relatively simple and gives us sufficient accuracy.

References

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