SOLAR PV POWER GENERATION

The RenewIT tool offers two parameters in order to define the amount of PV power installed on the Data Centre. These parameters are the installed peak power and the available roof area. Both parameters are used under the same hypothesis and for the same goal, determine the number of PV panels installed. In one hand, if the user specifies the installed peak power, the tool calculates the number of PV panels necessaries to achieve this peak power and informs of the required area to install this capacity. In the other hand, if the available are is specified the tool calculates the amount of PV panels that can be placed in this area and informs of the installed PV capacity.

AREA OCCUPIED

In order to determine the number of modules that will be installed or the necessary area to do the installation, it is crucial to know the area occupied by one module. The area occupied by one module, will be function of the module area itself and the distance between the PV rows (D). The module area is determined by the characteristics of our selected PV module [1] while the distance between the PV rows is calculated in order to ensure at least 4 hours of sun at the winter solstice. In order to achieve that, the distance (D) must be greater than the product H·k, where H is the height of the PV panel and k is a dimensional factor that depends on the latitude of the location [2] . As can be seen in Figure 1, the height of the PV panel will depend on the tilt angle (β).

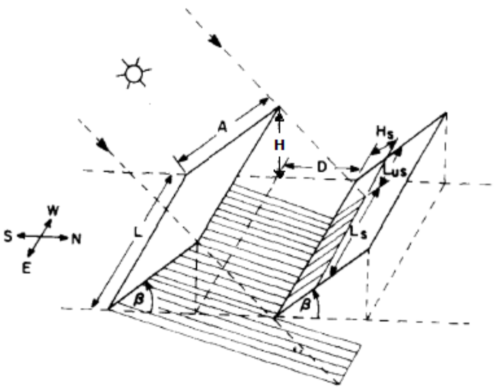

Figure 1 Geometric relation between panel tilt, row space and solar height.

Assuming that the installation will use fixed modules oriented to the south, the tilt angle can be optimized in order to achieve the highest annual irradiation [3] . The equations used to calculate the optimal tilt are different depending on if the location latitude is higher or lower than 45º.

OPTIMAL TILT FOR LOCATIONS WITH LATITUDE < 45º

The optimal tilt, for locations with latitude smaller than 45º, can be calculated using equation 1 and knowing the latitude (φ) of our location.

$$\beta = 3.7 + 0.69 \cdot |\varphi| \qquad (1)$$

OPTIMAL TILT FOR LOCATIONS WITH LATITUDE > 45º

At higher latitudes, higher differences between summer and winter irradiation are found. As a result it can be anticipated that as the latitude increases, the optimal tilt angle should give priority to the collection of summer over the collection of winter irradiance.

For regions with latitude higher than 45º large deviations are found between the optimal tilt that is predicted with dynamic simulations [[3] [6] and the tilt calculated with equation 1. This is a consequence of significantly more clouds, hence more diffuse irradiation which is best captured by flat tilted modules. Moreover, at lower tilt higher number of modules can be installed due to the fact that lower distance between PV rows are needed in order to avoid shading effect. As a result, equation 2 is used for locations with latitudes higher than 45º.

$$\beta = (3.7 + 0.69 \cdot |\varphi|) - 10 \qquad (2)$$

Once the tilt and module length (A) are known it is possible to calculate the height (H) of the module using equation 3.

$$H = A \cdot \sin(\beta) \qquad (3)$$

After calculate the height of the module it is possible to know the inter row distance (D) applying equation 4. The value of the k factor can be known with the latitude of the location, as is shown in Figure 2. If the user has specified the available roof area, knowing the inter row distance (D) it is possible to know the total area occupied by one module and consequently the number of modules that can be placed in the roof area. At the same time if the user has specified the PV power capacity, knowing the capacity of one module it is possible to calculate the number of modules that needs to be installed. Multiplying the number of modules by the area occupied by one module it is obtained the total roof area necessary to do the installation.

$$D = H \cdot k \qquad (4)$$

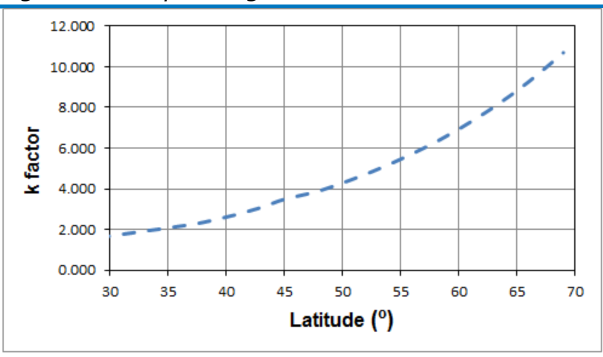

Figure 2 Evolution of factor k with the location latitude [2].

The resultant inter row distance tries to ensure that no shading effect will occur between panels. Even so the k curve shown in Figure 2 does not achieve that for locations with latitudes higher than 45º. For these locations is necessary to leave a huge inter row space in order to avoid shading effect, in contrast very low percentage of the available area is effectively used to place PV panels. In order to overcome these issues two actions are taken into account. First, equation 2 will be used in order to achieve lower shadow projection between rows and secondly, the PV production will be corrected in order to consider the shadow effect in these locations where this phenomenon has a higher presence.

PV PRODUCTION CORRECTION DUE TO SHADING EFFECT

In order to know the production of the PV power capacity installed a set of TRNSYS [7] simulations have been launched with the objective of characterize the ratio of energy produced by each kilowatt peak of PV power installed. These ratios have been characterized for each of the locations available in the tool and without consider the shadow effect between panels. In order to apply the correction over the PV production different correlations found in literature are used [8-9]. These correlations are deduced for different ranges of the locations latitude.

PRODUCTION CORRECTION FOR LOCATIONS WITH 45º < LATITUDE < 55º

The ratio of production, for locations with higher latitude than 45º, is corrected following the methodology and results obtained in [8] . This methodology characterizes the relative shading losses (s) between panels. The relative shading losses is calculated with the annual irradiation on a titled unshaded module (H_β) and the annual irradiation on a titled module considering mutual shading ($H_{\beta,shad}$), equation 5. These losses are characterized for different shading angles (α) and module tilts, as is shown in Figure 3.

$$s = 1 - \frac{H_{\beta,shad}}{H_\beta} \qquad (5)$$

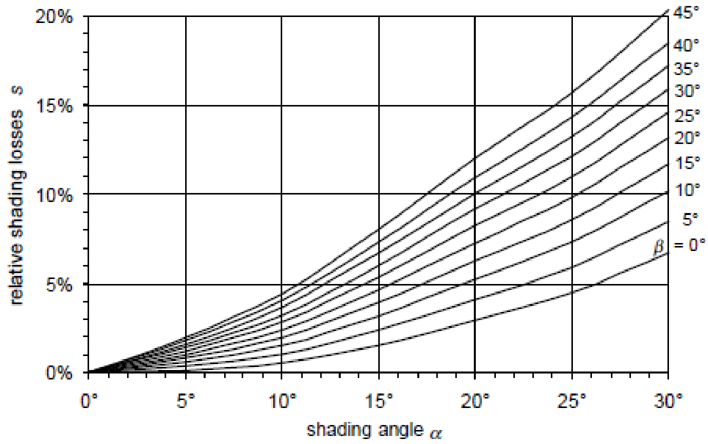

Figure 3 Relative shading losses for different panel tilts at locations with latitudes between 45-55º [8].

PRODUCTION CORRECTION FOR LOCATIONS WITH LATITUDE > 55º

The results shown in Figure 3 are valid for locations with latitudes between 45-55º, for the rest of locations with latitudes higher than 55º the correlation shown in Figure 4 will be used. This correlation is obtained following the same methodology presented above and characterizes the relative shading losses in locations with higher latitudes [9] .

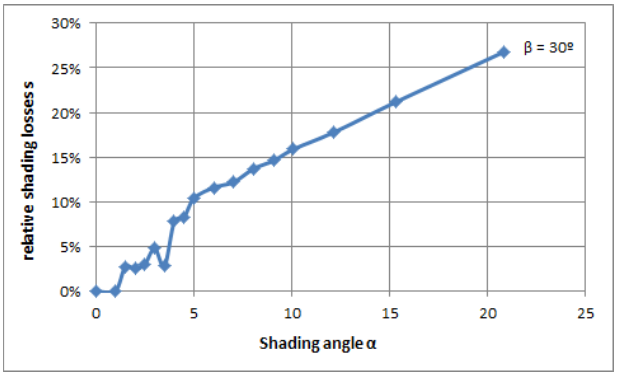

Figure 4 Relative shading losses for a 30º panel tilt at locations with latitudes higher than 55º.

In both cases, the shading angle can be know after apply equations 6 and 7. Equation 6 calculates the exploitation factor (F) which is later used with the module tilt in equation 7 to know the shading angle.

$$F = \frac{A}{(D + A \cdot cos(\beta))} \quad (6)$$

$$\alpha = \arctan(\frac{F \cdot \sin(\beta)}{1 - F \cdot \cos(\beta)}) \quad (7)$$

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