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Overview of the Orientation of Solar Generator Surfaces for Photovoltaic (PV) Systems

One of the most readily, espacialy for households as well as for higher installed power, renewable energy techniques to generate electrical power, are the solar photovoltaic (PV) systems. In the designing process of solar photovoltaic systems, a certain number of factors have to be considered in order to be able to capture maximum of solar radiant energy, for a given location, as ambient conditions, PV cells and the entire necessary equipment. Considering these factors, it allows to gain the maximum power with the existing equipment for the given radiation.

Keywords: PV system, orientation, solar generator surface

1. Introduction

One of the most important characteristics of the renewable energy sources, towards the fossil resources and besides that of an environmental friendly energy production, is that those resources are free available and unlimited, i.e. wind or sun. The solar energy has, in plus, also the vital property of being more flexible, allowing such to be widely used in many applications, from water heating to electricity power generator systems, independent of the locations complexity.

To install a more efficient PV system, it is essential to start in the design stage with the right product selection, based on correct information's about the incident solar irradiance on the PV panels that will allow an accurate estimation of the electricity production. The positioning of the PV panels has to be done based on the maximum sunlight to improve the highest efficiency.

2. Solar modules and solar generators

Mono-and polycrystalline Si solar cells consist of a large-area diode, with a light-exposed barrier layer. When the light photons meet the solar cell, based on the internal photoelectric effect, an electron / hole pair is generated. Due the strong electric field E in the barrier layer, the electron / hole pairs are quickly separated before they can recombine. On the electron, cause of their negative charge, acts a force opposite to field direction; therefor they accumulate in the n-type region. The holes move in the field direction and accumulate in the space-charge-free part of the p-type zone. The open circuit voltage U_0 of a solar cell is always slightly smaller than the diffusion voltage U_D.

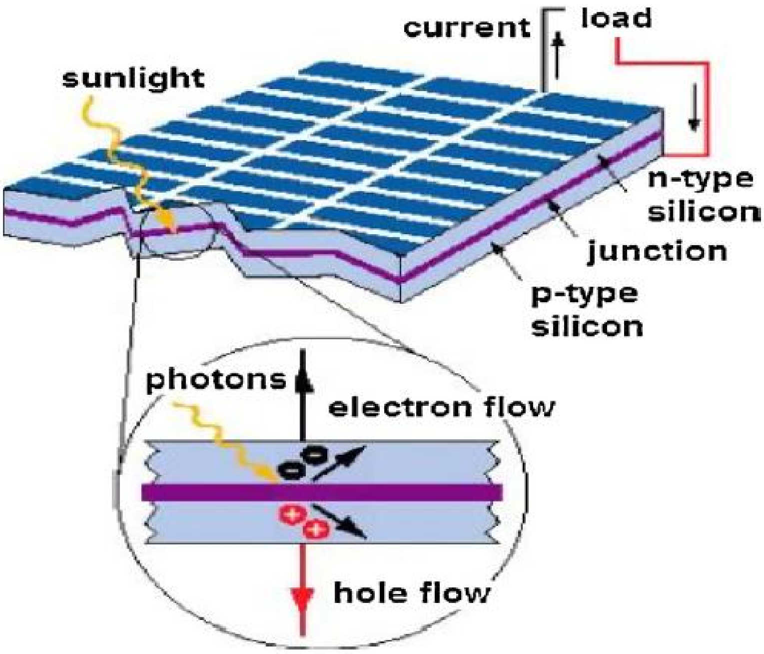

Figure 1. Photovoltaic effect in PV cells [4]

If the front and rear contacts will be short circuited via an external conductive, the electrics charges produces by the internal photoelectric effect can immediately drain off from the respective zones. The space charge and the electric field suffer no reduction, over the barrier layer lies further the diffusion voltage U_D and for the given irradiance intensity flows a proportional short circuit current I_{SC}.

In practice, the n-type layer on the cell surface is usually much more heavily doped than the p-layer, therefore denoted by n +. The solar cell, as a whole, must be electrically neutral that's why the unbalanced space charge region extends well into the p-region. The equivalent circuit for a single PV cell illustrates those correlations. With the series resistor R_S and parallel resistor R_P, the internal losses of a photovoltaic cell are shown, figure 2.

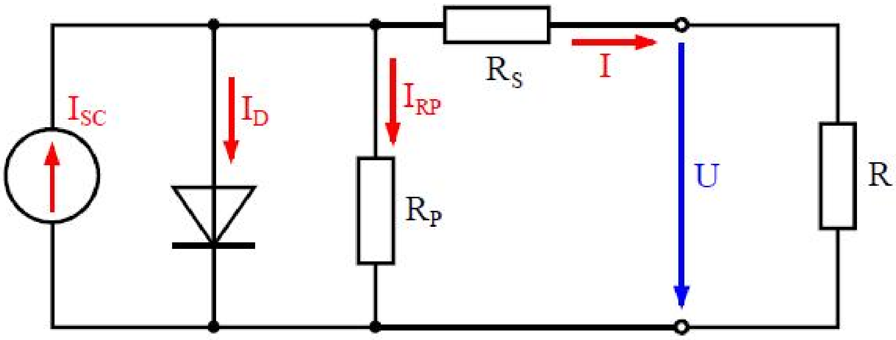

Figure 2. Equivalent circuit of a solar cell (no load: R = ∞, short circuit: R = 0).

As shown in figure 2, the model contains a current source I_{SC}, one diode with e current ID and the voltages on the resistances' that allow expressing the current of the solar cell [1]:

$$I = I_{SC} - I_D = I_{SC} - I_S \cdot \left(e^{e \cdot U/mkT} - 1\right) = I_{SC} - I_S \cdot \left(e^{U/U_T} - 1\right), \qquad (1)$$

where I_{SC} – short-circuit current of the solar cell; IS – saturation current in the blocking direction; ID – current trough the diode; UT – thermal voltage (25.7mW at 25^{O}C); T – temperature in K; e – elementary charge $1.6 \cdot 10^{-19}$ As; k – Boltzmann constant ($1.38 \cdot 10^{-19}$ Ws / K); m – emission coefficient (1 ≤ m ≤2).

Another important equation is that of the open circuit voltage [3]:

$$U_o = \frac{m \cdot k \cdot T}{e} \cdot \ln\left(1 + \frac{I_{SC}}{I_S}\right) = U_T \cdot \ln\left(1 + \frac{I_{SC}}{I_S}\right) \approx U_T \cdot \frac{I_{SC}}{I_S}, \qquad (2)$$

where $I_{SC} >> I_S$.

If for each point of the I = f{U} curve the power will be calculated, the power curve P = f{U} is obtained. At open circuit and short circuit the solar cell provides no power. At a certain point, called MPP (Maximum Power Point), the output of the solar cell performance is maximized and reaches the value $P_{max} = P_{MPP}$, figure 3.

The maximum power point $P_{max} = P_{MPP} = U_{MPP} \cdot I_{MPP}$, which the solar cell is able to give, is always less than the product of the open circuit voltage U_0 and short – circuit current I_{SC}. As a photovoltaic system must always bear both open-circuit voltage as short circuit current, the ratio of P_{max} to $U_0 \cdot I_{SC}$, besides the efficiency η, represents a measure of a solar cell. This ratio is called fill factor (FF) [1]:

$$FF = \frac{P_{max}}{U_0 \cdot I_{SC}}. \qquad (3)$$

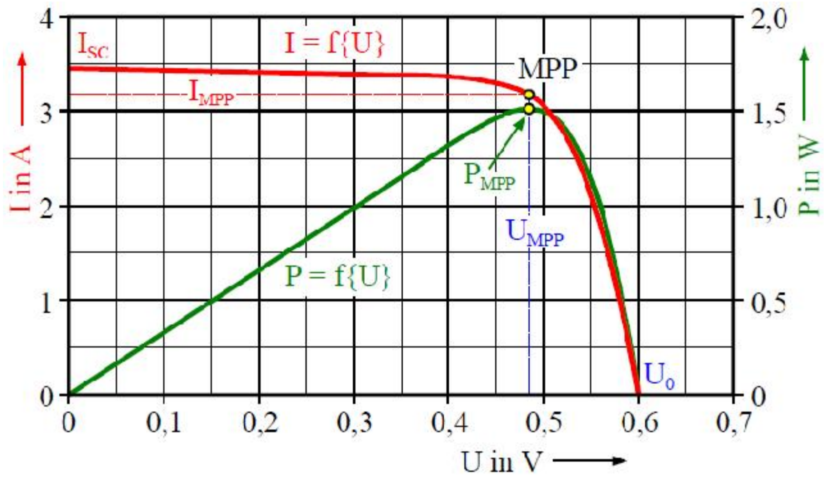

Figure 3. I=f{U} and P=f{U} curves of an SI PV cell at a solar irradiation of 1 kW/m^2, cell temperature 25^{o}C [6]

3. Calculation of the radiation on inclined surfaces

For the technic use of solar energy it is important to know the course of the apparent path of the sun through the day. The from the Earth seen Sun position, is described by two angles h_S – sun elevation above the horizontal plane and solar azimuth γ_S - deviation of the horizontal projected connecting line to the sun from south direction, figure 4.

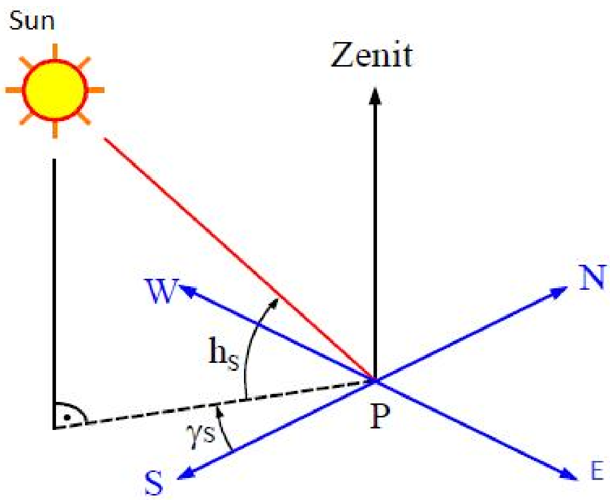

Figure 4. Description of the solar position (viewed from a point P on Erath) through the angle h_S and γ_S [5]

The irradiation of a solar generator and thus the produced electric energy can be significantly increased with a proper chosen orientation towards the sun. Solar generators with at an angle to the horizontal plane, better use the direct solar radiation. Depending on the angle of attack, season and weather conditions, the radiation can be considerably increased. Positioning the solar generators at the angle relative to the horizontal plane, the irradiation at the solar generator may be raised towards the irradiation of a plane surface. Taking into account the solar height h_S, the solar azimuth angle $¥_S$, the inclination angle , and the solar generator azimuth angle ¥, the direct radiation of the solar generator surface G_{GB} can be computed from the direct irradiation on a horizontal surface G_{HB}, figure 5.

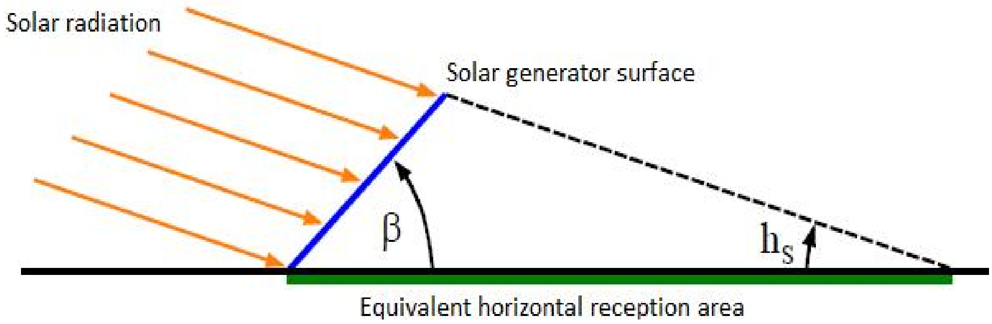

Figure 5. Pitching of the solar generator by an angle [5]

$$G_{GB} = G_{HB} \cdot \left(\frac{\sin}{\tanh_S} \cos(¥_S - ¥) + \cos \right) \tag{4}$$

The direct irradiation on the solar generator surface is maxim, when the sun is normal to the generator surface. Since solar altitude and azimuth of the sun vary during the day, a two-axis tracking system is needed - but expensive – to maintain the optimal irradiation throughout the day upright. The produced power as well as the full load hours can accordingly increase with up to 30% [2].

Because of the higher effort for creation and maintenance, the lower reliability of complex systems, before realizing tracking system it has always to be clarifying whether the saved money would not be better invested in additional solar modules.

In general, solar generators are mounted at a fixed angle , without seasonal tracking. Under ideal conditions, i.e. sunny weather all year round a surface receives the maximum direct radiation when angle is about the same with the latitude ¨. In regions with a higher proportion of diffuse radiation – as Romania – is a slightly lower tendency somewhat better.

4. Conclusion

The most spread application in field of renewable energy production is given by the PV systems. This paper provided an overview of the orientation for the solar generator surface, in order to achieve a higher efficiency of the PV generation systems, indicating the best size order of different parameters, as the solar generators angle to the horizontal plane as well as economic criteria, that justifies or not tracking system for PV.

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