SIMULATION OF OPTIMAL ANGLE INCLINATION FOR SOLAR PANELS

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Abstract. The use of a tracking system to keep the PV cell/panel perpendicular to the sun can boost the collected energy by 10 - 100% depending on the circumstances. The use of a tracking system greatly improves the power gain from solar radiation. This background goes into further detail on the operation of solar cells and the reason tracking is needed. The different tracking technologies are also described and how they compare to one another. Different power applications require different tracking systems. For certain applications a tracking system is too costly and will decrease the max power that is gained from the solar panel. Due to the fact that the earth rotates on its axis and orbits around the sun, if a PV cell/panel is immobile, the absorption efficiency will be significantly less at certain times of the day and year.

Key words: tilt angle, photovoltaic modules, calculation, autonomous solar power plant, radiation.

Introduction

In this work, we performed calculations to determine the angle of inclination of photovoltaic panels for one autonomous solar installation. According to the calculations, the optimal angle of inclination of solar panels for this autonomous power plant is 24.2 degrees.It is known [1] that the energy flux density incident on the module depends on the angle of inclination of the module to the Sun. When the panel surface and solar radiation are perpendicular to each other, the radiation flux density will be maximum. When the angle of inclination changes, the radiation flux density decreases. Thus, the angle of inclination significantly affects the radiation incident on the surface of the module. If the angle of inclination is equal to the latitude of the module, the radiation flux has the maximum possible value. In this work, we performed calculations to determine the angle of inclination of photovoltaic panels for one autonomous solar installation. According to our calculations, the optimal angle of inclination of solar panels for this autonomous power plant is 24.2 degrees. Photovoltaic cells are a combination of multiple photovoltaic converters mounted on a rigid or flexible substrate. Each solar panel panel consists of two silicon wafers with conductive copper strips. At the point of contact, the plates have the thinnest coating: one boron, the other phosphorus. Under the influence of photons from sunlight, areas with excess and deficiency (so-called "holes") of electrons appear in the photocell. At the junction of the plates, at the p-n junction of the semiconductor, an electrical generating effect occurs.

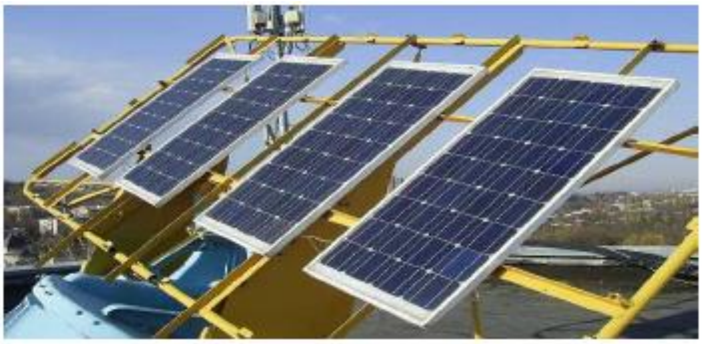

Fig 1. Solar panels

The performance of solar panels depends largely on the orientation of the crystals and the purity of the silicon. Over the past decades, scientists have been struggling to improve these parameters and reduce the cost of producing purified homogeneous silicon. Not only silicon can act as a semiconductor material, but the operating principle of solar panels remains the same. To produce monocrystalline solar panels, purified, pure silicon is used. This type of solar panel looks like silicone honeycombs or cells that are connected into one structure. Moreover, such batteries are worth choosing at least because of their high 20% efficiency. This is a good indicator for solar panels. The appearance of the panels is shown in Figure 1.

The information of radiation on the horizontal surface are usually available and can be applied to calculate the energy received on an inclined surface. The total monthly average daily radiation HT is the sum of direct, diffuse and reflecting components according to [1]:

$$H_T = H + H_D + H_R.$$

The method applied in this paper for calculating HT is the KT method. The general form of this method considers both the slope and azimuth angles. Given the lack of access to complete reliable information on different cities and parts of Iran, we had to use the existing relations to estimate solar radiation. A computer code was used in MATLAB to carry out the calculations. The code used relations presented in the previous section to calculate total daily radiation on a tilted surface within a month at the -10° to 90° tilt angles. Afterwards, the angle corresponding to the maximum total radiation on a tilted surface was obtained and introduced as the optimum monthly tilt angle.

Results and discussions

Since the planned panels will be installed directly on the roof of the canopy, electric chargers need to take into account the installation angle of the solar modules. The calculation is carried out according to the method [2]. To determine the daytime illumination of an inclined area, it is necessary to divide the average monthly solar radiation illumination in kWh/month on an area with the same angle of inclination as the solar panels by the number of days of the month.

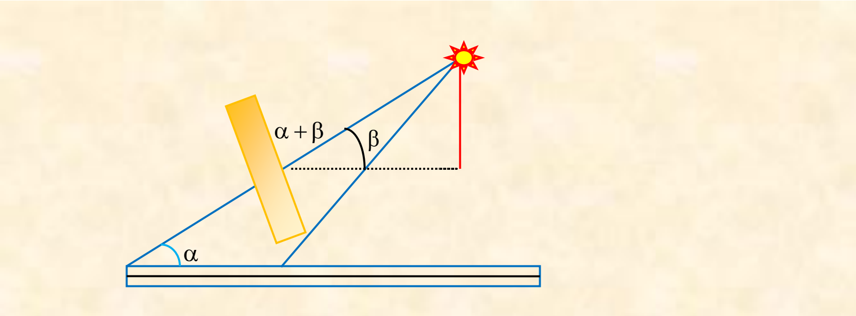

Fig 2. Sun rays falling on coals

If the module is facing the Sun so that the rays fall perpendicular to its surface, then its angle of inclination is equal to the polar angle of the Sun (Fig. 2.)

$$\beta = 90 - \alpha, \quad (1)$$

where is the elevation angle – the height of the Sun in the sky, measured in degrees from the horizontal position. The declination is zero on the days (March 22 and September 22), positive when it is summer in the northern hemisphere, and negative when it is winter there. The declination reaches a maximum of 23.45 on June 22 and a minimum of -23.45 on December 22.

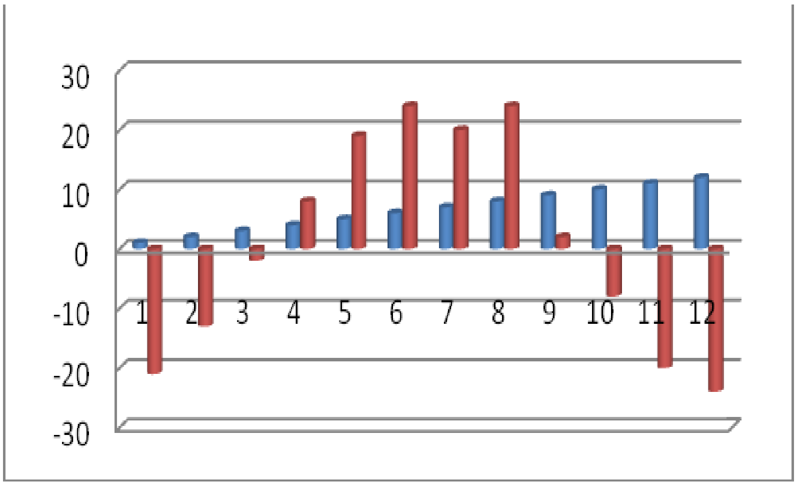

Figure 3. Declination angle by month

Declination can be calculated using formula (12), degrees

$$\Delta = 23.45^{\circ} \cdot \sin\left(\frac{360}{365}(\delta - 81)\right) \quad (2)$$

where is the day of the year, for January -1, for January 2 = 2 and so on. According to the results obtained, the optimal angle of inclination of solar panels for fully autonomous power supply of an electric charging station will be 24.2 degrees.

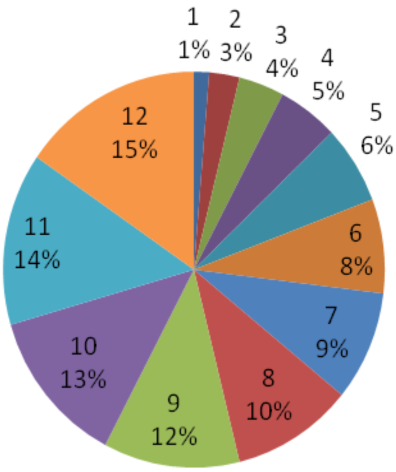

Figure 4. Coal distribution by month

By applying the above procedure and the data from the six stations listed in Table 1, the monthly, seasonal, and yearly optimum tilt angles and total radiation on the inclined panel are calculated using the above Equations. Table 2 shows the monthly optimum tilt angle of the six stations. The monthly optimum angles range from ´2.61˝ (June) to 69.87˝ (December). Obviously, negative values appear in the determination of optimum tilt angles, such as for June in ARNASAY.

The seasonal optimum tilt angles are the mean of the monthly optimum tilt angles in a season, while the yearly optimum tilt angles are the average of the monthly optimum tilt angles in a year. Figure 5 shows the mean daily global solar radiation collected fixed at zero and at optimum monthly, optimum seasonal, and optimum yearly tilt angles for each month at six stations. As shown in the figure, the mean daily global solar radiation on a solar collector fixed at the monthly optimum tilt angle shows a significant increase compared to the horizontal and yearly collectors. Moreover, the mean daily global solar radiation at the optimum tilt angle is generally more than that for the horizontal collector, especially in the spring and winter.

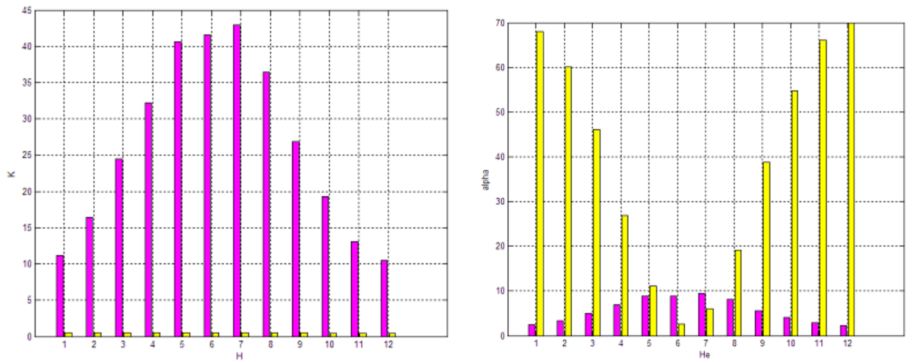

Figure 5. The mean daily global solar radiation on a solar collector

Conclusion

The energy flux density incident on the module depends on the angle of inclination between the module and the Sun. When the panel surface and solar radiation are perpendicular to each other, the radiation flux density will be maximum. When the angle of inclination changes, the radiation flux density decreases. Thus, the angle of inclination significantly affects the radiation incident on the surface of the module. If the angle of inclination is equal to the latitude of the module, i.e. e. , the radiation flux has the maximum possible value.

In summary, the use of a tracking system greatly improves the power gain from solar radiation. This background goes into further detail on the operation of solar cells and the reason tracking is needed. The different tracking technologies are also described and how they compare to one another.

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