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Effect of Tilt Angle of Solar Panel on Power Generation

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A B S T R A C T

The tilt angle of a photovoltaic panel plays a crucial role in determining its performance and energy output. Research has shown that the optimal tilt angle for a PV panel varies depending on factors such as geographical location, season, and application. This study aims to investigate the effect of tilt angle on the performance of PV panels in order to optimize energy production. By analysing the relationship between tilt angle and solar irradiance, this research seeks to provide valuable insights for improving the efficiency of PV systems.

Keywords: Photovoltaic panel, tilt angle, solar irradiance

1. INTRODUCTION

Photovoltaic power generation has witnessed remarkable worldwide growth in recent years. As countries and industries increasingly prioritize sustainable and renewable energy sources, the utilization of photovoltaic panels has expanded extensively (Moosavian et al., 2013). The growth in PV power generation is particularly significant in regions with abundant sunlight and supportive government policies. In response to the escalating demand for clean energy, the photovoltaic industry has made substantial advancements in technology, efficiency, and cost-effectiveness. This has further propelled the widespread adoption of solar energy systems across various sectors. Consequently, the global solar energy market has experienced a substantial surge, with PV installations contributing significantly to the overall capacity.

The increasing investment in research and development, coupled with the declining costs of solar panels and associated equipment, has played a pivotal role in driving the expansion of photovoltaic power generation on a global scale. Furthermore, the integration of innovative financing models and incentive programs has spurred the deployment of solar energy infrastructure in both developed and developing nations (Wen et al., 2021).

The output of a photovoltaic panel, which refers to the electricity generated by the panel, is influenced by various factors. One of the crucial factors that affect the output of a PV panel is the tilt angle of the panel plane. The tilt angle determines the angle at which the panel is oriented with respect to the sun, and it plays a critical role in optimizing the panel's performance. The tilt angle affects the amount of sunlight that the PV panel receives, thereby impacting its efficiency in converting sunlight into electricity. The optimal tilt angle varies based on factors such as the geographical location of the panel and the time of year. By adjusting the tilt angle according to these factors, the PV panel can capture maximum sunlight and enhance its overall output.

In addition to the tilt angle, other factors such as solar irradiance, temperature, shading, and the orientation of the PV panel also influence its output. Understanding and optimizing these factors are essential for maximizing the electricity generation from PV panels and ensuring the efficient utilization of solar energy.

2. LITERATURE REVIEW

Research on the optimal tilt angle of solar panels has been conducted in various locations, with different methods and models used to determine the best angle. (Ajao et al., 2013) found that in Ilorin, Nigeria, the optimal tilt angle is 22°, while (Tlijani et al., 2017) reported that in Tunisia, the best angle varies depending on the orientation and can range from 0° to 90°. (Hailu & Fung, 2019) suggested that in the Greater Toronto Area, Canada, the optimal tilt angle is between 37° and 47°, with the panel needing to be repositioned four times a year. (George & Anto, 2012) also emphasized the importance of considering local factors, such as atmospheric conditions and the movement of the sun, in determining the optimal tilt angle. Research on the optimal tilt angle of PV panels has yielded various findings. (Zhao et al., 2010) and (Sado et al., 2021) both emphasize the importance of this angle in maximizing energy capture, with Zhao suggesting daily adjustments and Sado advocating for a fixed angle. (Quinn & Lehman, 2013) introduces a formula for estimating the optimal angle, taking into account the influence of cloudy conditions. (Hailu & Fung, 2019) further refines this, suggesting that the angle should be changed four times a year and that a 15° change in orientation has minimal impact on energy capture. These studies collectively underscore the significance of the tilt angle in PV panel performance and offer different approaches to optimizing it.

3. METHODOLOGY

3.1 Specification of PV system

The location of the plant is specified with meteorological data with latitude of 26.82 N and 75.82E. For the simulation the capacity of power plant is 9kWp. the module rated capacity is 320 Wp. Total number of modules installed is 28 and module area is 46.9m2.

3.2 Solar radiation on inclined plane

Intensity of solar radiation received on earth surface depends on the latitude of that location. As the latitude increase the intensity reduces and vice versa. For maximum receiving of sunlight, it is essential to keep the plane perpendicular to solar radiation i.e. angle equal to the latitude. The radiation reached on earth surface and on inclined surface is represented in figure 1.

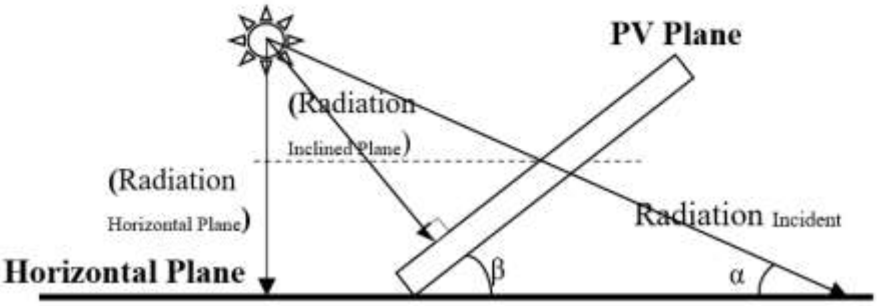

Figure 1: Radiation on inclined surface

The radiation received on horizontal plane is called global horizontal radiation that is composed of direct and diffuse radiation component. The radiation received on inclined plane is given by the following equation (Honsberg & Bowden, 2019).

$$\text{Radiation}_{\text{inclined plane}} = \text{Radiation}_{\text{horizontal plane}} \times \frac{\sin(\alpha+\beta)}{\sin\alpha}$$

The simulation data is represented in table 1.

		0° degree		20° degree		30° degree	
	GlobHor	GlobInc 0°	EUseful	GlobInc 20°	EUseful	GlobInc 30°	EUseful
	kWh/m²	kWh/m²	kWh	kWh/m²	kWh	kWh/m²	kWh
January	111.6	111.5	887	144.5	1170	155.7	1261
February	132.3	132.3	1048	161.1	1284	169.5	1350
March	171.6	171.4	1334	190.5	1483	193.0	1503
April	187.8	187.8	1441	193.7	1483	189.7	1452
May	193.4	193.4	1469	187.6	1423	178.4	1353
June	175.9	175.9	1345	166.9	1275	157.0	1200
July	150.1	150.1	1157	143.3	1105	135.6	1046
August	144.7	144.7	1123	143.8	1116	138.8	1078
September	147.4	147.3	1141	157.2	1219	156.7	1216
October	141.9	141.8	1098	164.2	1278	169.5	1321
November	115.2	115.0	900	145.5	1155	155.5	1237
December	108.5	108.4	855	143.8	1159	156.3	1262

4. RESULTS

For simulation the PV software PVsyst is used. The data is analyzed for grid connected PV power plant. After submitting the values of power plant capacity, module and inverter type the simulation is performed for different tilt angle of plane. The results are tabulate here. Following results have been observed.

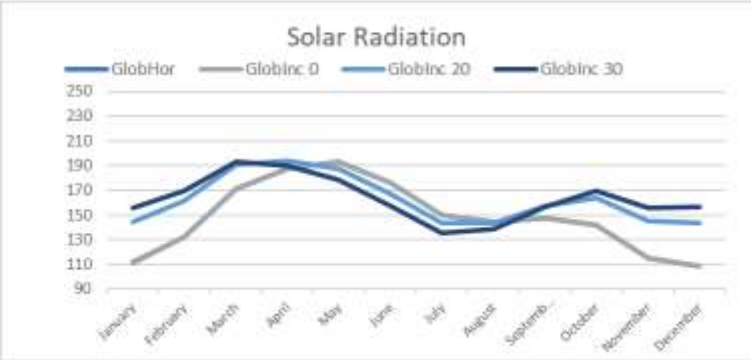

Figure 2: Graph1

In graph 1 the distribution of global horizontal radiation and global inclined plane is represented. the distribution represents the variation of radiation throughout the year. The maximum GHI is received on month of May, but the maximum radiation received on inclined pane at 20° and 30° is in month of April and March respectively.

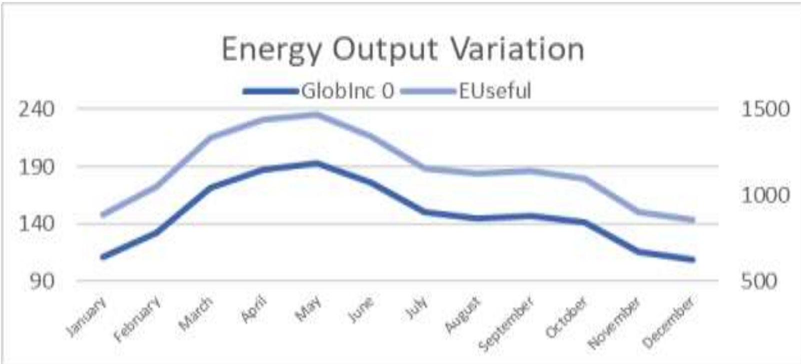

Figure 3:Graph 2

In graph 2 the distribution of global inclined plane and energy produced is represented. the distribution represents the variation throughout the year. The maximum GNI is received on month of May, and maximum energy is also produced in the same month.

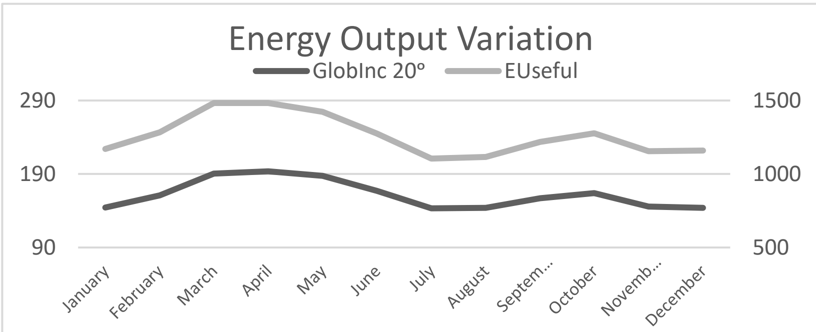

Figure 4:Graph 3

In graph 3 the distribution of global inclined plane and energy produced is represented. the distribution represents the variation of output of PV plane inclined at 20° throughout the year. The maximum GNI is received on month of April, and maximum energy is also produced in the same month.

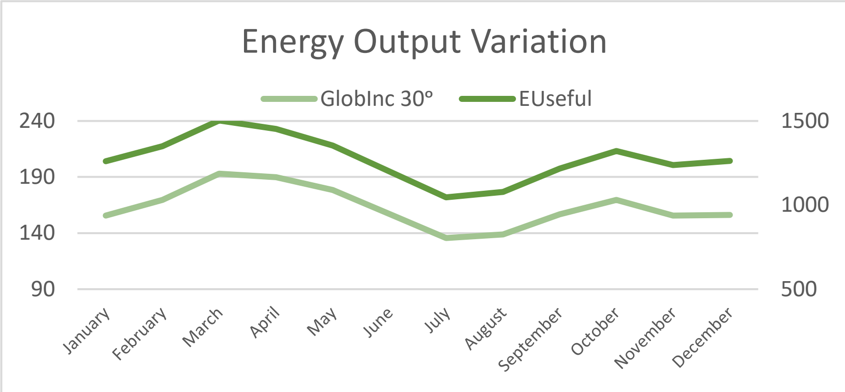

Figure 5: Graph 4

In graph 4 the distribution of global inclined plane and energy produced is represented. the distribution represents the variation of output of PV plane inclined at 30° throughout the year. The maximum GNI is received on month of March, and maximum energy is also produced in the same month.

5. CONCLUSION

In conclusion, the research findings demonstrate that the tilt angle significantly impacts the performance of PV panels. It was observed that adjusting the tilt angle according to the specific geographical location and season can lead to a substantial increase in energy output. These results underscore the importance of carefully considering the tilt angle when designing and installing PV systems to maximize their efficiency and energy production. Further studies in this area could focus on developing automated tilt adjustment mechanisms to optimize PV panel performance in real-time, ultimately contributing to the widespread adoption of solar energy technology.

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