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Research paper



Investigation on Tilt Angle Calculation and Irradiation on Solar Panels

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Abstract

The optimum choice of the tilt angle for the solar panel in order to collect the maximum solar irradiation is the most challenging work. The sun is in a different place in the sky is the idea. The sun light is different in different seasons and captures more energy by adjusting the tilt angle of the panels according to the season. Solar panels should face it as squarely as is reasonably possible throughout the day. Solar panels are installed differently based on their geographic locations throughout the world. Solar radiation differs from season to season with area wise based on the latitude of earth and sun. The influence of the tilt angle on the solar energy collection and concluded that during winter season wide change in the tilt angle. The factors affecting the optimum tilt and azimuth angles are the regional composite feature of the solar radiation, validating the importance of the regional optimization design in improving the solar energy collection. The radiation has been calculated by calculating various factors. By setting the latitude to the location and then change the tilted surface for different seasons of the year to absorb the solar power received.

Keywords: *Geographic Location; Latitude; Radiation; Solar Panel; Tilt angle.*

1. Introduction

The solar panels are used to produce electricity and are contamination free power source. Moreover it is a good alternate to fossil fuels. Solar panels are able to extract the energy from the sun and change it into electrical power. Traditional electricity is produced from fossil fuels which generate more eco-friendly contaminations. But the usage of solar panels in the houses helps combat greenhouse emissions and decreases the environmental pollution. Solar powered Photo Voltaic (PV) panels convert sun light into electrical power by stimulating the electrons in the silicon cells consuming photovoltaic effect. Solar power generation is prepared with fixed PV panels. This approach of producing the power has a reduced amount of efficiency. Maximum power tracking algorithms are established to maximize the efficiency. Further the positioning of the solar panels gets fascination. The panels are placed affording to suns position. For the tracking purpose sensors have been utilized and the sensor output is fetch to microcontroller. The microcontroller based programs have been written so that the panels have been fixed to concentrated intensity position. After these matters the tilt angle becomes focused. It is an important for attaining optimum energy from the panels. The PV arrays are more capable when they are below sun rays. Mathematical models have been established to compute various performance constraints to maximize the efficiency. The performance and efficiency of the solar panels rest on many factors such as sort of panels, material used consideration of adaptation losses, environmental factors, state of the solar panels etc. Among these factors numerous factors are considered in this review paper.

2. Methodology

Some authors have been carried out season based [1, 3, 8, 9] analysis like winter, autumn, summer and spring seasons. Ekadewi et al [9] installed solar collectors in Surabaya to calculate the optimal tilt angle. They found different angle of optimiztion during diverse seasons. Quite a few authors did the work based on optimization of solar energy monthly based [9], daily based [8] and yearly based. Optimum tilt angle calculation have been analysed for various countries like Malaysia [2, 4], India [6], China [1] have been undergone in this review paper and choosing some towns in Sichuan for analysis. This survey paper focused on the optimization of tilt angle for maximum solar power output. By keeping this in mind the survey is based on season based analysis, mathematical model based analysis, Malaysia, India and china country based analysis. Finally future scope has been given for upcoming scientists.

2.1. Mathematical model based analysis

Elhab et al. [2] analysed to minimize the shading and subsequently increasing solar collector efficiency by using mathematical model. He installed the solar system in Kualalumpur to acquire optimum result. Hassane et al. [7] established the optimal tilt angle for maximum solar energy collection. Authors established a quadratic regression model to foretell annual optimal tilt angle for maximum solar radia-

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tion collection in Mediterranean region. Agarwal et al. [3] used a mathematical model for estimating optimum tilt angle and alignment for the solar collector. Ekadewi et al. [9] established a mathematical model for the profit of farmers and attained optimal value of tilt angle.

2.2. Analysis based on season

Zhenghao Jin et al. [1] deliberated about the optimum tilt and azimuth angles of solar collection panels. They also analysed the motivation of the solar collector installation angle on the solar energy collection during winter season and establish that there is an extensive change in the tilt angle. The optimal tilt angles over the year and in winter season had huge differences which can be 20˚ for a single town and can be bigger when varied among 6 towns ranged from 20 to 35 over the whole year and 30˚ to 55˚ in winter season. For the selected 6 towns the optimal azimuth angles were fluctuating from -10˚ to 10˚ over the year and from -5˚ to 10˚ in winter season. The suggested azimuth angle should be ranged from -20 ˚ to +20 ˚ and the tilt angle should be within latitude + or -25 ˚. The maximum decrement of the solar energy collection can amount to as great as 29.5% for the tilt angles and 6.5% for the azimuth angles. Agarwal et al. [3] used optimal tilt angles for several seasons (Spring, autumn and summer) distinctly. The authors developed different models for optimum tilt angles. The authors found that optimum seasonally tilt angle is maximum in winter 57.33 and minimum 2.67 in summer by Liu and Jordan model. The authors also found that optimum seasonally tilt angle is maximum in winter 57.83 and minimum approximately zero in summer by another model namely Badescu model. Moreover the authors also did analysis based on fixed angle panel and have its own demerits. During winter season solar panel captured more energy of 81 to 88% compared to optimum tracking. In spring, summer and autumn the efficiency of capturing energy is lower. They got 74 to 75% in spring/autumn and 68 to 74% in summer. Since the sun travels large area it cannot capture more energy. Kamal Attari et al. [8] estimated a performance analysis for grid connected Photo Voltaic system in a daily basis for a single year. A 5 kWp PV system is mounted with a latitude 35.7595˚N and longitude 5.8340˚W and about 49m above sea level. Temperature sensors and a pyranometer establish the monitoring equipment of the grid connected PV system. They collected the data of various meteorological parameters for analysis purpose. The yearly electricity transported to the grid was found to be 6411.3kWh. The authors compared the average yearly final output with other systems in diverse locations and its value was found by 4.45 kWh/kWp and the annual performance ratio of the installation was found by 79%. Ekadewi et al. [9] establish optimal tilt angle during several seasons and facing diverse regions. The authors established a solar collector and mounted in Surabaya-Indonesia, the finest tilt angle during March 12- September 30 is varied between 0-40˚(face to the North) and during October 1- March 11 is between 0-30(face to the South). Other option is mounting two collectors that are one facing to the east to be used in the morning and the other one to the west in the afternoon. The optimum tilt angle for these locations is 36˚ -39.4˚. It is a benefit associated to collector installed to the North or South. For collector facing to the North necessities alteration from 0-40˚ (March 12- September 30) and alteration the orientation to the South with angle modification from 0-30˚ (October 1- March 11).

Table 1: The optimum tilt angle calculated in numerous directions for Surabaya on March, 2011

Time	0910	0940	1120	1340	1440	1610
North	9˚	9˚	8˚	9˚	9˚	10˚
East	43˚	35˚	10˚	-25˚	-40˚	-63˚
South	-9˚	-9˚	-8˚	-9˚	-9˚	-10˚
West	-43˚	-35˚	-10˚	25˚	40˚	63˚

The (-) sign means would face in the opposite direction. For exmple: at 11.20, the optimum tilt angle for facing South surface is 8˚. It means the collector would face North instead of South with tilt angle 8˚ to get further radiation.

2.3. Malaysia based analysis

Elhab [2] did a modelling of Solar panels to minimize the shading and accordingly cumulative solar collector efficiency by using mathematical model and visual basic application which is mounted in Kuala Lumpur to get optimal result. Lastly the authors settled that the poorest shading effects occurs during December and an optimal flat distance between solar collector rows for a flat arena is 2.66m for a 2m high collector, in the meantime, for field with steps and inclined arena, the plan of solar panel depends on slope or tilt angle β which is presented. The suitable angle for Kuala Lumpur location is (β=10˚). It is also concluded that the tilting angle of a solar collector should be suitable to obtain maximum solar radiation and to avoid shading. Khatib et al. [5] showed that optimization of tilt angle is mandatory in peninsular Malaysia.

2.4. India based analysis

Agarwal et al. [3] did a comparative analysis for optimizing tilt angle to obtain maximum radiation. His members mounted the system in India. Basharat et al. [6] conversed about minimum and maximum values of total solar radiation at annual optimal tilt angles, gains in annual average total solar radiation at annual optimal tilt angles, loss of solar energy and change in solar potential have been estimated in diverse regions. Minimum and maximum values of total solar radiation at yearly optimum tilt angles were 28.97 MJ/m^2-day (April) and 19.08 MJ/m2-day (January) respectively for Aligarh and 24.31 MJ/m^2-day (April) and 16.10 MJ/m^2-day (December) for NewDelhi. Improvements in yearly average total solar radiation on optimally inclined surface in association to a horizontal surface were 12.92% (monthly optimum tilt angle), 11.61% (seasonal optimum tilt angle) and 6.51% (annual optimum tilt angle) for Aligarh. For NewDelhi, the improvements were projected as 13.13% (monthly optimum tilt angle), 11.80% (seasonal optimum tilt angle) and 7.85% (annual optimum tilt angle).

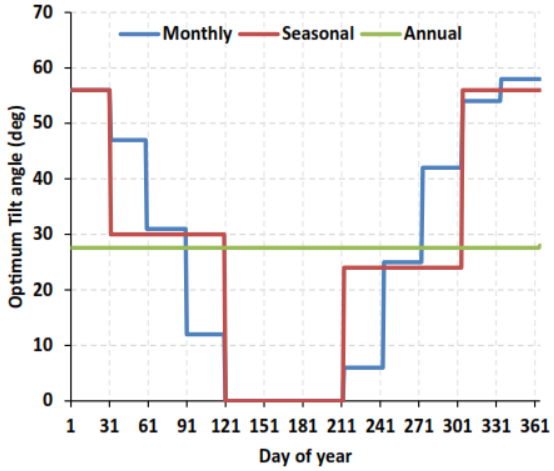


Fig. 1: Variations of monthly, seasonal and annual optimum tilt angles for South facing surface in Aligarh

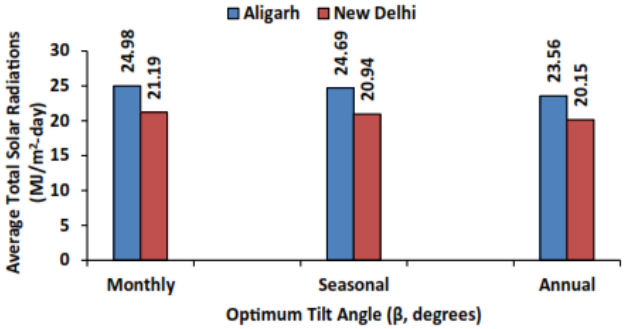


Fig. 2: Comparison of average maximum total solar radiation for Aligarh and NewDelhi.

2.5. Other countries based analysis

Zhenghao Jin et al. [1] deliberated about the azimuth tilt and optimal angles of solar collection panels. The solar collector connection angle on the solar energy collection for six towns in western Sichuan and finished that during winter season extensive alteration in the tilt angle. The longitudes, elevations and latitudes and of these towns are as registered, the varieties of which are 100.0-103.06˚ E, 29.0-32.8˚ N and 2664-3949 m, which are cover the western Sichuan area and fit to the high-altitude area. Additionally, the yearly averaged temperatures of the six towns were changing from 2.1-9.0˚ C, and had the typical features of the cold area when related with that in Harbin and Beijing, of which were 4.2˚C and 12.3˚ C. Kamal Attari et al. [8] appraised a performance investigation for grid connected PV system in Tangier in a daily basis for a single year.

3. Future scope

The goal line of this review paper has been encountered by concluding the future scope for solar based projects. The possibility of changing the tilt angle and azimuth angle of Photo voltaic arrays in various seasons and site based will improve the amount and worth of solar power. Solar trackers produce more electrical power associated to fixed position solar panels. In the immediate future cadmium telluride based solar cells substituting current silicon based solar cells. Further cadmium chloride based cells will be established to generating more solar power. Magnesium based panels are more fascinating due to its safety and low cost feature. Also efficiency of the panels upgrade, storing developments and equipment competences will donate effective solar power with low costs. As per GTM Research report solar tracker installation growth will be 21% from 2017 to 2021.

4. Result and Discussion

The tilt angle value is varying from season to season and country based variations. The optimum tilt angle deliberate in many directions for Surabaya is specified and its value is diverse for different directions. In India Aligarh and NewDelhi are deliberated for analysis. The seasonal optimum tilt angle for Aligarh is 11.61% and for NewDelhi is 11.8%. The monthly optimum tilt angle for Aligarh is 12.92% and for NewDelhi is 13.13%. The annual optimum tilt angle for Aligarh is 6.51% and for NewDelhi is 7.85%. The assessment of average maximum total solar radiation for NewDelhi and Aligarh is presented for monthly, seasonal and annual. So for the optimization of tilt angle calculation various seasons and geographical location of the place should be deliberated.

5. Conclusion

The optimization of tilt angle for exploiting the solar power output is case to case it is adjustable. Since the tilt angle value is varying from season to season and country based variations. In the mathematical model based analysis the authors have considered various parameters for optimal tilt angle calculation. The optimum tilt angle calculation for various months, yearly and daily analysis results have

been analysed based on various authors work. The solar radiation values changed from season to season. Further the analysis of tilt angle for different countries were also compared and discussed. The factors affecting variations of optimum tilt and azimuth angles are analysed.

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