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Review Article

Review on Optimization of Tilt Angle for Solar CSP for effective steam generation

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Abstract

Ample of Solar power is available in universe . It can be used for various applications . One of them is steam generation . Parabolic shaped dishes Concentrating Solar Power (CSP) technology can be found one of the most important option for generating renewable electricity at the required scale .The paper presented here , we have tried to do the optimization of tilt angle of Solar concentrators by using Taguchi Method . This is a statistical approach to optimize the variable process parameters and improve the quality of concerned components that are manufactured. The objective of this study is to illustrate the procedure adopted in using Taguchi Method to find best tilt angle for CSP . First, a Taguchi experiment was used to perform an efficient experimental design and analyzed the robustness of the tilt angles for fixed south-facing PV modules. The objective is to maximize the steam generated from the modules .

Keywords: *Solar CSP ,tilt angle, Taguchi, steam generation*

1. Introduction

In India the amount of solar energy incident on a solar collector in various time scales is a complex function of many factors including the local radiation climatology, the orientation and tilt of the exposed collector surface and the ground reflection properties. The performance of a solar collector is highly influenced by its orientation and its angle of tilt with the horizon. This is due to the fact that both the orientation and tilt angle change the solar radiation reaching the surface of the collector (Ahmad, *et al*, 2009). Our main objective is to maximize the solar power by varying the tilt angle and slope in Ahmednagar .

There are various devices for absorbing the solar radiation. The Sun rays are to be always focused onto the absorber plate. The collector has to be rotated by tracking system, but the tracking system is very costly so we cannot use this for every system economically. Due to this reason the solar collector is fixed either monthly, seasonally or yearly pattern, based on our requirements (Agarwal, *et al*, 2012).

In last few years, many authors have presented models to Predict solar radiation on inclined surfaces. Some of these models apply to specific cases; some require special measurements and some are limited in their scope. These models use the same method of calculating beam and ground reflected radiation on a tilted surface. The only difference exists in the treatment of the diffuse radiation. The approximation commonly used for converting the diffuse component value for a horizontal surface to that for a tilted one is that sky radiation is isotropically distributed at all times (Danny, *et al*, 2007).

We are using Taguchi method to find out best possible tilt angle for Solar CSP , in Ahmednagar . Taguchi method is a statistical method developed by Taguchi and Konishi . Initially it was developed for improving the quality of goods manufactured (manufacturing process development), later its application was expanded to many other fields in Engineering (Srinivas, *et al*, 2012) .

Professional statisticians have acknowledged Taguchi's efforts especially in the development of designs for studying variation. Success in achieving the desired results involves a careful selection of process parameters and bifurcating them into control and noise factors. Selection of control factors must be made such that it nullifies the effect of noise factors. Taguchi Method involves identification of proper control factors to obtain the optimum results of the process. Orthogonal Arrays (OA) are used to conduct a set of experiments. Results of these experiments are used to analyze the data and predict the quality of components produced.

Concentrated Solar Power from Parabolic dishes can be used to generate steam for laundry application. Before implementation of the solar system the steam is generated using HSD for its end use and

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consumption. The system can be integrated with its existing process.

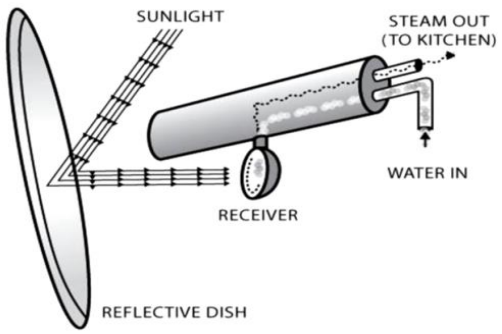

Fig.1 Working of parabolic dish solar collector for steam generation

2. Review of Optimizing tilt angle

Solar energy is a very large, inexhaustible source of energy. Quantitative assessment of solar radiation incident on a tilt plane is very important to engineers designing solar energy collecting devices, to architects designing buildings, and to agronomists studying insolation on vegetation on mountain slopes. To me*et al*l these requirements, one should know the intensity of radiation falling upon the sloping surface and its variation over a period of one year.

(M. Jamil, *et al*,2009) found that monthly based optimum tilt is different for different stations . Season based optimum tilt is also different for different stations . Annual based optimum tilt is approximately equal to latitude of the location. All the eight diffuse radiation models yield the same optimum tilt .They also found that the average optimum tilt angle at New Delhi for the winter months is 47.5^{o} (latitude + 19°) and for the summer months 13^{o} (latitude -16°). This, in general, is in agreement with the results of many other researchers.

(Abhishek, *et al* , 2012) found in comparative approach for the optimization of tilt angle to receive maximum radiation , that , the solar radiation output of solar collector is investigated at various tilt between angles 0° to 90° for south facing to calculate daily and monthly optimum tilt angles, seasonal optimum tilt angles and yearly optimum tilt angle for different locations in India. The optimum tilt angles increases during the winter months and reaches a maximum of 62° in December. When the monthly optimum tilt angles were used, the yearly collected solar radiation was 2.500775× W/m^{2}day .They also stated that , The proper tilt and azimuth angle choice is by far more important for photovoltaic systems design than solar thermal system design.

(Danny, *et al*, 2007) studied determining the Optimum Tilt Angle and Orientation for Solar Energy Collection Based on Measured Solar Radiance Data, carried out an approach of employing sky radiance model for determining an optimum tilt angle and orientation for maximizing annual solar yield was conducted. The whole year (2004) 10 minute horizontal radiation and sky radiance data recorded in Hong Kong were used for the analysis. The incident solar radiation data on various inclined surfaces facing different orientations were calculated. The optimum tilt angle was found to be around 20◦ due south, which would receive the annual solar yield over 1598kWh/m2. The findings support that a solar collector with the tilt angle approximately equal to latitude of the place could receive maximum annual solar radiation.

(Feng, *et al*, 2015) investigated , in their work , Optimizing the Tilt Angle of Solar Collector under Clear Sky by Particle Swarm Optimization Method, carried out the particle swarm optimization method to search the optimal tilt angles for solar collectors in Taiwan. Herein, solar radiation considered is calculated by using empirical model suitable for clear sky situation. The results would be useful for practical applications. The optimal tilt angles are positive (i.e. facing toward south) for most of the months of year whereas negative (facing north) for summer months from May to July. The annual optimal tilt angles for locations Taipei, Taichung, ,Tainan, Kaohsiung, Hualien and Taitung are 22.4^{0}, 21.5^{0}, 20.5^{0}, 20.2^{0}, 21.3^{0} and 20.5^{0}, respectively .

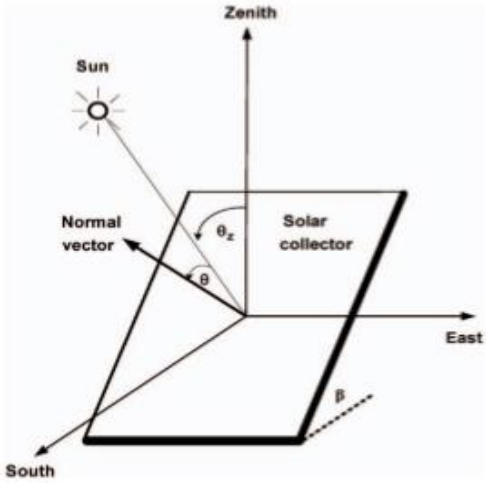

Fig.2 Geometry of solar collector

(Vineet, *et al*, 2012) , found that , the seasonal optimum tilt angles for Chennai is minimum as compared to other locations in winter, spring and autumn but in summer Nagpur goes to minimum seasonal optimum tilt angle. The optimum tilt angle in June goes to a minimum zero degree as indicated by all the models. They mentioned, Solar module oriented towards the South gives the greatest values of electrical energy for all the chosen angles and for the angle of 30° generates the greatest registered value for electrical energy. This is an optimal tilt angle in the summer. When the sun's rays fall normally on the module's surface, the incident sunlight power is maximum

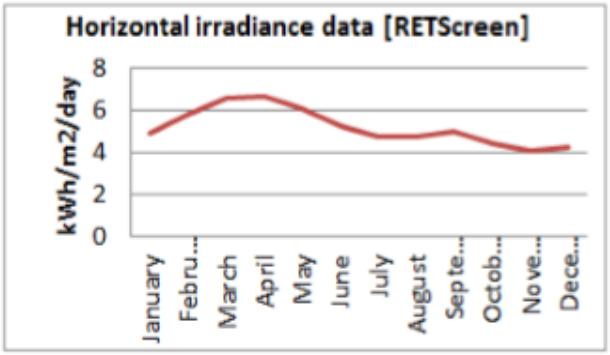

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Fig.3 Daily Solar radiation data for Chennai

(Pavlovic, *et al*,2010) Determined optimum tilt angles and orientations of photovoltaic panels in NIS , SERBIA and found that, Solar module oriented towards the South gives the greatest values of electrical energy for all the chosen angles. Solar module oriented towards the South for the angle of 30° generates the greatest registered value for electrical energy. This is an optimal tilt angle in the summer. Generated electrical energy for solar module oriented towards the South 30° and East (West) for the angle 0° differ by 0,54%. An increase in solar radiation of 28.76% results in the increase in power of 24.78%. (Navaneet, *et al*, 2014) found that Liu and Jordan model gives results which are quite close to the results of the data measured at the solar panel installed at IIT Rajasthan. This model was used for determination of monthly average and seasonal average of optimal tilt angle. It has been concluded that the average optimum tilt angle at Jodhpur for winter months is 47.6^0 and for summer mPonths 12^0. It is hence suggested that seasonally adjusted tilt angle should be preferred. However, yearly average fixed tilt can be used in many general applications (e.g. domestic water heating) in order to keep the manufacturing and installation costs of collectors low. The loss in collected radiation for the yearly average fixed angle is around 12.7% as compared with the optimum tilt at Jodhpur.

3. Ongoing Efforts

It is found that main problem is the expensive present system of steam generation , by using HSD fuel . For washing, drying, and pressing of all types of cloths and handle all kind of garments from 300 to 3000 pieces a day , huge expenses are to be done. So taking effort to reduce labour cost and improve quality of output by this system of Parabolic CSP. Also to improve the effective steam generation, best tilt angle is to be found out with the help of Taghuchi method .

Conclusions

1) The best way to collect maximum daily energy is to use tracking systems. A tracker is a mechanical device that follows the direction of the sun on its daily sweep across the sky Thermal analysis is a good technique to control carbides, shrinkage and micro-shrinkage formation.
2) In the northern hemisphere, the optimum orientation is south facing and the optimum tilt angle depends only on the latitude.
3) There is a wide range of optimum tilt angle as recommended by different authors, and they are mostly for specific locations.
4) A simple mathematical procedure for the estimation of the optimal tilt angle of a collector is presented based on the monthly horizontal radiation.
5) Taguchi Method involves identification of proper control factors to obtain the optimum results of the process.

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