Performance Evaluation of Bifacial and Monofacial modules in vertical and latitude mounting at South India using PVsyst

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Abstract. Producing power in Solar PV panel is simple as all the required data on the performance of various types of panel are available in the field scientific research. As we advance into the future newer and newer technologies are created and evolved according to the needs of the generation. Similarly, in the field of Solar Photovoltaics we have evolved the face of power production from one side to double side. Bi-facial panels are the latest trends which not only produces power on the side facing the sun but also the side facing away. Experimenting on the Bi-Facial Panels to determine the performance, the orientation and placement for the highest LCOE (Levelized cost of electricity) by obtaining the power and radiation data. In this project we have developed various experimental approach to acquire the data required for a Bi-Facial panel setup. The results derived have proved that the new vertical mounting’s performance is slightly below the latitude mounted Bifacial Pv panel for the equator regions. Even though the daily comparisons led to a reduction in power level the continuous running of the system proved otherwise.

1. Introduction
Conventional solar panel based on monocrystalline, polycrystalline and amorphous technology utilize the solar radiation incident on one side of the solar panel to produce electrical energy. However, the bifacial solar panel, which has the solar cells on both sides can also utilize the ground reflected solar radiation to produce electrical energy. Thus, provides more power output. The power output and powerconversionefficiencyof the bifacial panel can be improved by increasing the ground reflectance (albedo). The bifacial solar panel without frame can have reduced potentialinduceddegradation(PID). It produces higher energy yield and allows flexible system installation as they absorb light from both sides the south facing may not be the best practice Because commercial bifacial panels are a relatively new product in the solar industry, there are a few reasons they have not been fully adopted into the mainstream market. Utilizing bifacial modules on the commercial/utility scale calls for new, system. The most efficient way to leverage both sides of a bifacial module is by setting them up on a ground mount with a 20-25-degree tilt. Bifacial modules are in both framed and frameless designs. It either has back sheets or dual glass. Most types use mono-crystalline cells.

2. Literature review
Like every good invention we require the previous works and knowledge to proceed on. Similarly, to start this study we have boosted our knowledge from a fundamental book for Bifacial panel published early on 2019
Joris et.al [1] has provided us the entire book based on the Bifacial panel this gives us the working and the in-depth knowledge required to start with this project. It also provides the Due to the lack of historical field data and gain based on albedo, height of installations and orientations, the Government and other agencies, still consider the bifacial solar panels as mono-facial solar panels, which affects the number of installations and definite energy gain. Shen Liang et.al [2] reviewed the crystalline bifacial performance char and simulated the thermal models. The international road to the global PV market and the banking requirements. In this paper the new C-Si bifacial PV performance. He studied and identified that the two types of factor that are performance categorization and bankability. Sub-models such as optical, electrical and thermal models. He also explored the challenges of characterization and simulation of the panel. Suresh Kumar et.al [3] explores the importance of maximum power point tracking in the factors that affect the soiling. However, reliable PV systems maybe they still have to clear up the soiling factors that are one of the most degrading factors over a period of time He also proved that 16-18% of the efficiency is affected by the soiling effects. This limitation is what makes PV unreliable and limited power dependent. Reza maghami et.al [4] provides a further explored the factors that affects the soiling in individual modules and the array’s output. Taking into account the shading and soiling losses for this efficiency calculation the author drafted the method for removal of dust from PV system using mobile and waterless cleaning to improve the performance of the panel. The author tested the pattern of soiling at different tilt angles. Monto mani et.al [5] has laid out the pathway for the challenges and the difficulties that the researchers face in this field of soiling and the status of overcoming the huddles. There are also valuable recommendations on how to efficiently propel the status in a steep linear improvement. The in-depth knowledge required to proceed further is also explained with extraordinary graphical representation. Patrick D et.al [6] suggested that when the soiling data that we required is not available to us the method of artificial soiling using the NIST-traceable components sprayed in a controlled environment to duplicate the effect of soiling provided is very closely predictable to the range of loss due to live soiling data. This method is one of the efficient as it is time consuming. The author concluded that the type of soil available in the nearby area also plays a predominant role in reducing the power output of the solar panel. Lin J. Simpson et.al [7] has went beyond the existing to acquire the data and the information to prove the importance and the effects of the Soiling of PV Modules. Statistical data related to the US government are provided with the required rate of research improvement that researches have to come up for PV panel coating. The author has also dived into the Coating for antisoiling basically these coating is not only dust resistant but also does not allow particles to stick on to the surface of the panel. LCOE Levelized cost of Energy’s effects due to the soiling is also quantified. King. B et.al [8] Researches from Arizona state university and Sandia National Laboratories Have extended the previous study by building up new stations for soiling based on the soil data collected from various places. They installed 10 custom made panels which are connected to the same DAS which is installed at different angles from 0° to 45°. They installed in 5 different locations and compared the results in his network. Jose Cano et.al [9] Researches from Arizona state university and Sandia National Laboratories have continued the previous setup work and have compared the values of power at the module and estimated the difference in the soiling effects of the panel in 5 different areas for tilt angles from 0°- 45°. Poonam R et.al [10] While analysing toward different factor one of the factors is shadowing & effect of dust particle. In this article the survey to this effect on overall performance of SPV is focused & an embedded System was design to solve the problem. the fabrication of such Automatic dust cleaner will overcome its demerits & will bring revolution in today’s scenario where each & every country is facing the challenge of energy crisis. Paulo Ayala et.al [11] A research station for photovoltaics purposes was installed under outdoor high irradiance conditions during 8 months at the Atacama Desert. Performance ratio of bifacial technology assuming only the nominal power of the front face reaches 96%, thin film reaches 90%, polycrystalline reaches 88% and monocrystalline reaches 78%. The soiling ratio decreases less than 2.5% during first two months and after it was found a natural
cleaning effect due to high humidity that occurs often at early morning and keep the soiling ratio at 0.94±0.01.

From the above we can conclude that frequent cleaning may decrease the transmittance of glass. Dust composition and local weather affects the soiling rate and energy output. Vertical mounting of bifacial modules could mitigate the soiling losses and therefore, regular cleaning of panels can be avoided. The latitude mounted bifacial panels would produce lower energy after three weeks when compared with vertically mounted panel, if they are not cleaned in the meanwhile. Vertically mounted modules with high bifaciality run at lower temperature than latitude mounted modules, with potential improvements in the performance ratio and long-term reliability. LCOE is lower in the case of bifacial solar PV system with improved albedo.

3. Methodology
PVsyst is a design and performance evaluation software which is available for a trial period of 30 days. This software is fully customizable from the ratings and arrangement of each cell of a module to the type of system incorporated. In this we will be designing a bifacial system with vertically mounted and latitude mounted array facing South/East. Which brings us to four different combinations of bifacial and four for monofacial Panels. To compare both case the output array power is fed to the grid and for power comparisons the number of panels are considered as eight in series connections.

| Case 1 | Case 2 | Case 3 | Case 4 |
|--------|--------|--------|--------|
| Orientation | N-S | W-E | N-S | W-E |
| Inclination angle | 90° | 90° | 13° | 13° |

The simulation was carried out for the latitude 13° (SRM institute of science and technology Kattankulathur) using the hourly radiation data of the year 2018 obtained from the weather station data logger available at the steam cooking plant. These values were entered in the meteo site files of PVsyst. Then the orientation is specified along with the number of modules as 8 in series. The string is limited to one with zero shading, no self-consumption and zero soiling losses. The simulation is run with an albedo value of 30 (Dirt) and bifaciality of 80%. The post processing and results are extracted for hourly power production of each day throughout the year and each case of bifacial system is compared with the monofacial system of the same. To provide much more randomization 3 days from each 3 seasons are considered.

4. Results and Discussion
To demonstrate the effective resultant, it is important to acknowledge that there are various random variables that affect the power output of a PV system. Mostly comprising of the switching losses and production efficiency losses. In this comparison most of these arbitrary losses have been made common to both types of panel so that they cancel each other.

4.1 Vertical orientation
The bifacial panels are oriented towards south for N-S and towards west for E-W. The E-W orientation is done facing west and east so as to see if the power production is increased towards the evening or morning. The following conclusions were derived from the hourly data graphs.
4.1.1 E-W oriented Bifacial system

The dates 13/01, 29/01, 07/04, 22/05, 20/10, 06/12 were analyzed. The above dates all are from 3 different seasons in India. The west facing vertical mounted panels have the advantage of producing power during late evenings. During the winter the production starts from 6:15 pm peaking around 2:00 pm. This peak current sometimes last around 4:30 Pm with some dip during low radiation (clouds obstruction). Similar reverse effects have been observed when the orientation is East There were longer duration in the morning. In both the cases lower power production during the noon hours were seen. During the Summer the similar effects were observed with a slight increase of 30-45 min in working hours. At the rainy days there is a decrease of 30-45 min in working hours. The graphs for 13/01 (Winter) and 07/04 (Early Summer) are displayed (Figure 1 and 2).
4.1.2 **N-S oriented Bifacial system.** The south faced vertical orientation of the Bifacial panel is the vertical version of the conventional placement of Solar panel the reason for tying out this type of placement is to analyze how much the diffused radiation affects the power production. During the summer this orientation produces from 6:15 am and peaks sometime around noon lasting till 2:00 pm. During the winter the similar situation occurs with a slight increase in peak power. Rainy days have a decrease of 30-45 min in working hours along with decreased power production due to lack of

![Graph](image)

**Figure 3.** Bifacial south oriented Vertical power production on 13/01.

![Graph](image)

**Figure 4.** Bifacial south oriented Vertical power production on 07/04.

radiation. The graphs for 13/01 (Winter) and 07/04 (Early Summer) are displayed (Figure 3 and 4).
4.1.3 Monofacial system. The Power production in this south facing vertical system mostly leans towards the horizontal global radiation curve and the peak power achieved is 1800Wp the duration is a little low than the bifacial. The graphs for 13/01 (Winter) and 07/04 (Early Summer) are displayed (Figure 5 and 6).

![Figure 5. Monofacial latitude power production on 13/01.](image)

![Figure 6. Monofacial latitude power production on 07/04.](image)

4.1.4 Comparative results for vertical mounting. Comparing the yearly performance of E-W vertical mounted bifacial orientation we can clearly see the drop in power production during the east facing system. This can only be explained by the lack of enough beam radiation falling on the front side of
the panel. When the same system is placed in west orientation the power output has doubled. The performance of N-S oriented panel is also higher than the E-W orientation this is due to the high amount of Power available during the noon time which the E-W orientation fails to capture. Comparing these results with the conventional Monofacial panel of south faced vertical orientation we can see a clear doubling in power output. Other null assumed losses like soiling and shading has very little or zero effect in this upright position of the panel.

4.2 Latitude oriented Systems

The coordinates of Kattankulathur in South India are 13.0827° N, 80.2707° E thus the most favourable tilt angle is 13° facing south. The bifacial panels were set up one facing east other west and south at an angle of 13° and the monofacial panel is placed at the conventional mode of 13° facing south.

4.2.1 E-W 13° tilted Bifacial orientation. The bifacial panel is tilted to 13° similar to the vertical mounting the dated hourly power Vs Time Vs Radiation graph is drawn from the advanced results During the winter the production starts from 6:15 pm peaking around 11:00 am. This peak current sometimes last around 1:30 pm with some dip during low radiation (clouds obstruction). Similar effects have been noted for East orientation.

During the Summer the similar effects were observed with a slight increase of 30-45 min in working hours. At the rainy days there is a decrease of 30-45 min in working hours. The graphs for 13/01 (Winter) and 07/04 (Early Summer) are displayed in the graphs (Figure 7 and 8).

| Type                  | Yearly power | Performance ratio |
|-----------------------|--------------|-------------------|
| E-W vertical (west)   | 3507         | 0.839             |
| E-W vertical (east)   | 1345         | 0.788             |
| N-S Vertical          | 4676         | 0.847             |
| Mono vertical         | 2346         | 0.822             |

Table 2. Vertical Orientation Yearly Power generation in KW.
4.2.2 *N-S oriented South faced Bifacial system*. During the summer this orientation produces from 6:15 am and peaks sometime after noon lasting till 2:00 pm. During the winter the similar situation occurs with a slight increase in peak power. Rainy days have a decrease of 30-45 min in working hours along with decreased power production due to lack of radiation. This Orientation provides lesser power during winter when compared to the E-W but compensates during the summer time. The graphs for 13/01 (Winter) and 07/04 (Early Summer) are displayed in the graphs (Figure 9 and 10).

**Figure 8.** Bifacial South facing latitude-oriented power production.

**Figure 9.** Bifacial South facing latitude-oriented power production.
4.2.3 **Monofacial 13° tilted south faced orientation.** The conventional setting of the present panel placement is the reference point for this entire study. The same dates were pulled out and the performance of this system was surprisingly similar to the Bifacial N-S south oriented 13° tilted system with a decreased winter power production. The graphs for 13/01 (Winter) and 07/04 (Early Summer) are displayed (Figure 11 and 12).

![Figure 10. Bifacial South facing latitude-oriented power production.](image)

![Figure 11. Monofacial vertical-oriented power.](image)

4.2.4 **Comparative results for 13° tilted orientation.** Comparing the yearly performance of E-W latitude tilt mounted bifacial orientation we can clearly see the drop in power production during the east facing system. Similar to the vertical mounted system. When the same system is placed in west orientation the power output has significantly increased. The performance of N-S oriented panel is also higher than the E-W orientation this is due to the high amount of Power available during the noon time
which the E-W orientation fails to capture. Comparing these results with the conventional Monofacial panel of south faced latitude tilt orientation we can see an increase of 250-550 W.

Table 3. Latitude Orientation Yearly Power generation in KW.

| Type                  | Yearly power | Performance ratio |
|-----------------------|--------------|-------------------|
| E-W 13° Latitude      | 5709         | 0.838             |
| (west)                |              |                   |
| E-W 13° Latitude      | 5040         | 0.837             |
| (east)                |              |                   |
| N-S 13° Latitude      | 5989         | 0.849             |
| Mono 13° Latitude     | 5431         | 0.838             |

This effect will be prominent even after distinctive effect of soiling on the panel as the bifacial also produces power on the rear side.

5. Conclusion and scope

Based on this study, the following can be concluded

- The Latitude mounted bifacial panel proves that the conventional tracking is useless for the Bifacial module.
- The bifacial module installed vertically and oriented east–west can generate more power during the morning and evening period and in the afternoon, it produces relatively low power.
- When compared to a monofacial module the power produce by vertical Bifacial N-S oriented is roughly 2.00 times higher.
- Vertical axis tracking proved to be the most efficient in intergrading the vertical mounting of a bifacial module the peaks co inside the individual panels mounted vertically. This arrangement and the horizontal arrangement will prove to be the best tracking for a vertical oriented Bifacial Module.
- Latitude tilted Bifacial Panel proved to produce 1000KW more than the vertical orientation of N-S panel
- Even though there is a significant increase in the power the effects of soiling will be a significant reducer in the case of performance.
- This study has high scopes in the Usage of next generation solar Panel. Bifacial Panel with an appropriate tracking system will prove to be an excellent Power Source System.

6. Reference

[1] Liang TS, Pravettoni M, Deline C, Stein JS, Kopecek R, Singh JP, Luo W, Wang Y, Aberle AG, Khoo YS 2019 Jan 16 A review of crystalline silicon bifacial photovoltaic performance characterisation and simulation Energy & Environmental Science 12 116-48

[2] Kumar, E Suresh, Bijan Sarkar, and D K Behera 2013 Soiling and dust impact on the efficiency and the maximum power point in the photovoltaic modules International Journal of Engineering Research & Technology (IJERT) 2 1-8

[3] Bhaduri, Sonali, and Anil Kottantharayil 2018 Mitigation of soiling by vertical mounting of bifacial modules IEEE Journal of Photovoltaics 9 240-244

[4] Farshchi, Rouin, Benjamin Hickey, and Dmitry Poplavskyy 2017 Jun 25 Light-Soak and dark-heat induced changes in Cu (In, Ga) Se2 solar cells: A macroscopic to microscopic study IEEE 44th Photovoltaic Specialist Conference (PVSC) IEEE 1459-1462

[5] Simpson LJ, Muller M, Deceglie M, Moutinho H, Perkins C, Jiang CS, Miller DC, Micheli L, Tamizhmani G, Tatapudi SR, Al-Jassim M 2017 Jun 25 NREL efforts to address soiling on
PV modules *In*2017 *IEEE* 44th *Photovoltaic Specialist Conference (PVSC)* *IEEE* 2789-2793

[6] King B, TamizhMani G, Tatapudi S, Rajasekar V, Boppana S 2015 Jun 14 Regional soiling stations for PV: Design, calibration and installation *In*2015 *IEEE* 42nd *Photovoltaic Specialist Conference (PVSC)* *IEEE* 1-4

[7] Cano J, John JJ, Tatapudi S, TamizhMani G 2014 Jun 8 Effect of tilt angle on soiling of photovoltaic modules. *In*2014 *IEEE* 40th *Photovoltaic Specialist Conference (PVSC)* *IEEE* 3174-3176

[8] Ayala P, Muñoz C, Osorio N, Hernández C, Zurita F, Gutierrez V, Ramírez G, Mancilla F, Valdivia P, Cuevas F, Ferrada P 2018 Jun 10 Bifacial Technology Performance Compared With Three Commercial Monofacial PV Technologies under Outdoor High Irradiance Conditions at the Atacama Desert. *In*2018 *IEEE* 7th *World Conference on Photovoltaic Energy Conversion (WCPEC)(A Joint Conference of 45th IEEE PVSC, 28th PVSEC & 34th EU PVSEC)* 0672-0675

[9] Burton, Patrick D, and Bruce H King 2013 Artificial soiling of photovoltaic module surfaces using traceable soil components *IEEE 39th Photovoltaic Specialists Conference (PVSC)* *IEEE* 1542-1545

[10] John JJ, Tatapudi S, Tamizhmani G 2014 Jun 8 Influence of soiling layer on quantum efficiency and spectral reflectance on crystalline silicon PV modules *In*2014 *IEEE* 40th *Photovoltaic Specialist Conference (PVSC)* *IEEE* 2595-2599

[11] Sarver, Travis, Ali Al-Qaraghuli, and Lawrence L Kazmerski 2013 A comprehensive review of the impact of dust on the use of solar energy: History, investigations, results, literature, and mitigation approaches *Renewable and sustainable energy Reviews* 22 698-733

[12] Mani, Monto, and Rohit Pillai 2010 Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations *Renewable and sustainable energy reviews* 14 3124-3131

[13] Sulaiman SA, Hussain HH, Leh NS, Razali MS 2011 Oct 20 Effects of Dust on the Performance of PV Panels *World Academy of Science, Engineering and Technology* 58 588-593