Simulation analysis of a 3.37 MW PV system using bifacial modules in desert environment

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Abstract: This study is conducted to investigate the performance of bifacial solar PV with high albedo in desert regions. High amount of radiation falls on the Arabian Peninsula where there is an average amount of 2200 kWh/m² annually and needs to be utilized as much as possible to get higher amount of energy. A 3.37 MW system is simulated by PVsyst software using two different scenarios which the first is without an axis tracker while the other is with a dual axis tracker to track the sunlight from all directions. When the tracking system is not included the yearly energy production set to be 6684 MWh/year where the system is simulated at a fixed mounting at a single direction facing the south at an optimum tilt angle of 25°. On the other hand, when the tracking system is set to be dual trackers at a minimum tilt angle of 0° and maximum tilt angle of 80° vertically, and minimum azimuth angle of -120 and maximum azimuth angle of -120° horizontally. There annual energy production is set to be 8897 MWh which has a gain of 25% using bifacial solar module with tracking system which can add a value to the solar PV projects and decrease the levelized cost of energy (LCOE).

1. Introduction

Solar energy has become one of the fastest growing industry in recent years [1]. There are several reasons that made the solar photovoltaic (PV) industry to become a trend in all over the world. One of these reasons is that solar energy is clean and environmentally friendly [2],[3]. Furthermore, there is a worldwide concern of the climate change and how carbon emissions affect the planet [4]. Solar energy depends mainly on sunlight where countries that have a good amount of radiation have the opportunity to power up some or all of their demand using this free, clean and reliable source of energy [5]. In desert environment, despite of having a huge amount of radiation falls yearly, there are some benefits need to be utilized such as albedo [6]. This work shows how important is the reflected radiation and how it affects the yearly energy yield using PVsyst software.
Bifacial technology in particular, utilizes the reflectivity of ground-based or the sunlight that reflected from the ground as a result, additional electricity is generated. Therefore, the surrounding environment and installation structure are highly important to be taken into consideration when selecting bifacial modules. Recent study showed that, the power gain of bifacial solar modules is ranged from 13% to 35% depending on the heigh of ground clearance and under sunny conditions while the rage could be from 40% to 70% under cloudy conditions. However, it is very difficult for the output power of the bifacial modules as it mainly depends on the surrounding’s albedo as well as the geometry in which cells are mounted [7]. Recently, results from La Silla, Chile, where a single-axis tracker with a 550-kW bifacial PV system proven a 12% increase in performance as the daily potential bifacial gains ranged between 8% to 14% for two single-axis trackers. The interest in bifacial photovoltaic (PV) technology has been renewed in the solar market which significantly promises the levelized cost of energy savings compare to conventional mono-facial solar PV modules[8], [9],[10]. Both sides of bifacial modules can collect the light and also the reflected light from the surrounding ground surface where there is it can provide a degree of concentration as well as it can solve space constrained deployments[11].

The increased output power to some degree off-sets the higher cost of manufacturing bifacial solar modules comparing mono-facial solar modules [12]. Moreover, cost is expected to be reduced through large scale manufacturing techniques [13]. Glass-glass modules are expected to stay and have longer operational lifespans that is related to better matching of its thermal properties of the package materials [14]. This also leads to a reduction in the levelized cost of energy (LCOE) from bifacial modules where bifacial modules can also be used with tracking system single-axis or dual axis to have an increase in the energy yield [15]. Bifacial solar PV technology could add values to not only industry by reducing the cost of energy especially in large projects but also add values to the environment by reducing the carbon emissions which result in climate change and other environmental disasters.

2. Methodology
A system of 3.3 MW grid-connected was simulated using PVsyst software. the panels chosen were bifacial solar panels to utilize the reflected light from the ground. The location of the system was in Riyadh, Saudi Arabia with a latitude of 25.00° N, longitude of 46.59° E and altitude of 654 m. Bifacial solar modules were used with the following specifications:

| Solar panel model name | JKM400M-72H-BDVP-Bifacial |
|------------------------|-----------------------------|
| Maximum output power (W) | 400 W |
| Maximum Voltage (V
  mpp) | 41 V |
| Maximum Current (I
  mpp) | 9.76 A |
| Open Circuit Voltage (V
  oc) | 48.8 V |
| Short Circuit Current (I
  sc) | 10.24 A |

To form a 3.3 MW system, 8424 bifacial solar panels were installed. Different albedo factors result in different energy yield[16]. The higher the albedo factor the better in terms of energy production. In the proposed location, the average radiation fall at Saudi Arabia is around 2200 kWh/m² annually [17],[18]. While the albedo factor for the sand is ranged from 0.25-0.42 [19]. Another important factor to be taken into account when considering albedo is the direction of the panels (tilt angle) which plays an important role in determining the highest energy yield to be obtained [20]. An optimal tilt angle could have an effect on the energy yield production from a range of 10-30% of the overall expected yield gain. Especially for large commercial projects it can really make a difference especially in terms of economic aspects. In comparison between bifacial versus mono-facial solar modules, bifacial solar modules can have additional power up to 20% over mono-facial, the additional power could be as high as 30-40% when using tracker to track the
sunlight during the year. These advantages make bifacial solar modules the trend and the future investment in solar [7]. As stated earlier, bifacial solar modules can be advantageous when there is good amount of reflected radiation is available and this could be only when the albedo is higher. Where the environmental condition depends mainly on the albedo of the surroundings where in desert environment the albedo higher and its range depends on the type of sand available at the location. Table 2 shows different categories of albedo with its percentages and expected yield gain.

Table 2. Categories of albedo with the expected yield gain

| Surface                        | Albedo   | Expected yield gain |
|--------------------------------|----------|---------------------|
| Water                          | 5-8%     | 4-6%                |
| Green grassland                | 15-25%   | 7-9%                |
| Concrete ground / while gravel | 25-35%   | 8-10%               |
| Dry sand                       | 35-45%   | 10-15%              |
| Old snow                       | 40-70%   | 15-22%              |
| Reflective roof coatings       | 80-90%   | 23-25%              |
| Fresh snow                     | 80-95%   | 25-30%              |

It is noticeable from Table 2 that fresh snow has the highest reflective albedo factor with almost 90% while water has the lowest with around 5% [21]. Another factor which might be adding an extra capital cost which is the coatings where roofs required to be coated with a while paint to increase the reflectivity that would be suitable for large projects where the gain is much higher[22]. Additionally, there is a potential method to increase the gain by 15-25% by using trackers which track the sun during the day resulting in an increase in the energy yield compared to fixed mounted solar panels.

Albedo is defined as the ratio of reflected irradiance to front incident irradiance and can be estimated using the following equation1 [23]. The measurement tool for albedo is called a pyranometers and to be installed on the frame of the PV modules.

\[
\text{Albedo} = \frac{\text{Reflected irradiance}}{\text{Front incident irradiance}} \tag{1}
\]

Where the potential of reflected irradiance can be utilized by the rear side of the module. This causes an extra production by the solar module which results in reducing the levelized cost of energy (LCOE). Another important factor which is the tilt angle which is the declination of the solar module on the surface towards the sun to get the maximum sunlight in order to produce the optimum and maximum output power. The declination \( \delta \), can be expressed as in the following equation 2.

\[
\delta = (23.45) \sin \left(360 \frac{284 + n}{365}\right) \tag{2}
\]

Where \( n \) is the day number between the year days. where the optimal inclination of the solar modules leads to higher gain as well maximum energy yield.

3. Result and Discussion
Simulation results were conducted for bifacial modules forming a PV system of 3.37 MW. Two cases were simulated one was bifacial solar modules without axis tracker at high albedo of 0.45. While the second simulation was with axis tracker considering high albedo as sand has in the deserts.
3.1. The system without axis tracker
The system of 3.37 MW system was simulated considering fixed mounting structure for the bifacial solar modules with a tilt angle of 25° and total of 8424 solar modules. This resulted in an annually energy yield of 6684 MWh/year with a performance ratio of 82.00% as shown in Figure 1.

Results also showed that high performance ratio with 82.00% at yearly production. Moreover, results indicated that the production increase at months that are in winter whereas decreases in summer which means high temperatures affect the performance of the system in terms of energy yield as well as degradation of the system. Furthermore, the energy yield at specific period is around 1984 kWh/kWp/year. Bifacial solar modules are better to be installed under a high albedo and with axis tracker to gain the maximum energy that can be produced.

3.2. The system with axis trackers
Axis trackers can track the sun path to gain as much energy as possible by tracking the sun daily. Two axis tracking was simulated to track the sun at all directions at minimum tilt of 0° to maximum tilt of 80° vertically and with a minimum azimuth of -120° to maximum azimuth of 120° horizontally. With the same configuration as in the system without tracker, the results show that with axis tracker, the yearly energy production increases to 8897 MWh/year with a performance ratio 81.47% as shown in Figure 2.
Figure 2. Main simulation results using PVsyst for the 3.37 MW with axis trackers.

In comparison to the same system without trackers, by using tracker there is an extra gain of almost 25% which definitely can add value to the project in terms of the levelized cost of energy where it could also reduce the space or the land needed for the project as bifacial modules produces higher energy than the traditional solar modules.

4. Conclusion
The development of solar PV technologies has been on a constant rise. By using bifacial modules with tracking system can gain extra energy than the traditional mono-facial solar modules. The simulated results showed that an extra energy production of more than 25% is gained by using bifacial solar modules with dual system tracking than the bifacial without tracking system or at a fixed tilt angle. This can happen when the albedo is higher where the albedo is 0.45 at the white dry sand in desert regions. Using bifacial solar modules could make the solar energy more reliable and consistent.

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