Energy simulation of p-PERC bifacial modules based on different installation environment

Yashuai Jiang¹, Guoping Huang, Hao Zhuang, Guan Sun and Jingnan Li
9 Beishan Road, Dagang New District, Zhenjiang City, Jiangsu Province, China

¹Email: jiangyashuai@cecsec.cn

Abstract. The bifacial-cell module can significantly increase the power output due to the back power generation gain, and is becoming research hot. In this paper energy simulation analysis is based on three types of systems in different regions, and the installation tilt, ground albedo and height above ground are compared respectively. The irradiation is dominating to produced energy. The modules located in Yinchuan under the situation of albedo 0.2, tilt 15° could generate 85.2 MWh/year, which is 6.1 MWh/year higher than the modules located in Beijing under the situation of albedo 0.8, tilt 30°. The modules generate more power under the situation that the installation tilt is close to latitude, the optimal tilt of Beijing, Yinchuan and Guangzhou is 30°, 30-35° and 15°. The higher the albedo of the ground, the greater the impact of tilt changes on produced energy. Meanwhile, the increasing height above ground promotes to the higher energy. And the produced energy is more sensitive to the variable value of ground albedo compared with height.

1. Introduction
Levelized cost of energy (LCOE) is becoming the key factor that restricts the construction of photovoltaic power station [1]. Researchers found that the applied solar modules with high efficiency could significantly reduce LCOE. There are two commonly methods to improve the efficiency. One is to increase the efficiency of solar cells, such as multi-busbar [2, 3], bifacial-cell [4, 5], N-PERT [6] and HJT [7]. Another is to optimize the circuit design, the structure of half-cell and shingled cell has been widely used [8-10]. There is no doubt that bifacial cell technology is becoming a hot spot in the market, the such modules could generate more than 5%-30% power compared with the conventional monifacial module. Meanwhile the bifacial cell technology showed better adaptability, which could be superimposed on PEPC, PERT, HJT, half-cell, multi-busbar, shingled and so on [4-6, 8-10]. According to International technology roadmap for photovoltaic (ITRPV) forecasts, the market share of bifacial cell is expected to be 20% in 2020 and will increase to 70% in 2030 [11]. Recently there have been relevant research reports on the influencing factors of bifacial-cell modules power generation [12-15], but there are many limiting factors on the back-side power generation gain, and single factor research is difficult to comprehensively evaluate. In this paper, PVsyst simulation software is used to compare the influence of site location, installation angle, ground reflectivity and height above the ground on the power generation performance, and theoretical analysis is carried out to provide guidance for the installation of bifacial-cell modules.
2. Project and simulation design
The simulation analysis system is based on PVsyst 7 version. PVsyst is mainly used to model and simulate photovoltaic power generation systems, analyze various factors that affect power generation, and finally calculate the power generation of photovoltaic power generation systems. The project capacity is set to 50kWp. Beijing (39.93°N, 116.28°E), Guangzhou (23.13°N, 113.32°E) and Yinchuan (38.48°N, 106.22°E) are geographical sites. They are distributed in three types of regions with different solar energy resources, and they have significant irradiation differences. The information of p-PERC bifacial-cell module shows as follows, Pmp 420Wp, Isc 10.9A, Imp 10.3A, Voc 49.1V, Vmpp 40.8V, bifacility factor 65%, the module size 2034*1000*30 mm. The temperature coefficient of Pmp and Isc is -0.35%/°C and 0.05%/°C respectively. The model type of inverter is Sungrow SG50KTL-M. The value of sheds spacing is 6.6m. The height above ground is from 0.5-2.5m with the step length 0.5m, the ground albedo is set to be 20%, 50%, and 80%. The installation tilt varies from 15°-50° with the step length 5°.

3. Results and discussion
3.1. The influence of albedo and tilt to produced energy
Increasing effective irradiance is the most effective way to increase energy generation, and the difference in latitude and longitude of different locations has a significant impact on irradiance. As is shown in Table 1, the produced energy of Yinchuan under the situation albedo 20% and tilt 15° is still much higher than that of Beijing under the situation albedo 80% and tilt 30°. The substantial increase in energy with the increase in albedo is also due to the growing backside irradiation. Meanwhile the modules generate more power under the situation that the installation tilt is close to latitude as the effective received irradiance is highest, the more the tilt deviates, the more energy loss.

Figure 1. The relationship between produced energy and tilt (a:Beijing, b:Yinchuan, c:Guangzhou).
To further analysis, the more energy produces, the less energy increases (Figure 1). On the one hand, the energy increase with ground albedo from 20% to 50% is higher than that with ground albedo from 50% to 80%. On the other hand, as tilt changes, the produced energy increases or decreases, the energy increase curve shows the converse result. Meanwhile, it is obvious that the relationship between produced energy and tilt is almost symmetrical along the axis of maximum produced energy point.

Table 1. The produced energy compared with different location, albedo and tilt.

| Location | Albedo | Beijing (MWh/year) | Yinchuan (MWh/year) | Guangzhou (MWh/year) |
|----------|--------|--------------------|----------------------|-----------------------|
|          | 20%    | 15.0               | 69.0                 | 85.2                  | 54.5                  |
|          | 20.0   | 70.2               | 87.0                 | 54.4                  |
|          | 25.0   | 70.9               | 88.2                 | 54.0                  |
|          | 30.0   | 71.2               | 88.9                 | 53.3                  |
|          | 35.0   | 71.1               | 88.9                 | 52.4                  |
|          | 40.0   | 70.6               | 88.5                 | 51.2                  |
|          | 45.0   | 69.8               | 87.5                 | 49.9                  |
|          | 50.0   | 68.6               | 86.1                 | 48.4                  |
|          | 50%    | 15.0               | 73.2                 | 89.9                  | 58.1                  |
|          | 20.0   | 74.3               | 91.6                 | 58.1                  |
|          | 25.0   | 74.9               | 92.7                 | 57.7                  |
|          | 30.0   | 75.2               | 93.2                 | 57.0                  |
|          | 35.0   | 75.0               | 93.2                 | 56.2                  |
|          | 40.0   | 74.6               | 92.8                 | 55.1                  |
|          | 45.0   | 73.8               | 91.9                 | 53.9                  |
|          | 50.0   | 72.7               | 90.7                 | 52.5                  |
|          | 80%    | 15.0               | 77.3                 | 94.4                  | 61.7                  |
|          | 20.0   | 78.3               | 95.9                 | 61.7                  |
|          | 25.0   | 78.9               | 96.8                 | 61.4                  |
|          | 30.0   | 79.1               | 97.3                 | 60.8                  |
|          | 35.0   | 78.9               | 97.3                 | 60.0                  |
|          | 40.0   | 78.5               | 96.9                 | 59.0                  |
|          | 45.0   | 77.8               | 96.1                 | 57.9                  |
|          | 50.0   | 76.8               | 95.1                 | 56.6                  |

a. The value of sheds spacing is 6.6m. The height above ground is 1.5m.
b. The global horizontal irradiation of Beijing, Guangzhou and Yinchuan is 1362.5 kWh/m²/mth, 1183.7 kWh/m²/mth and 1654.6 kWh/m²/mth.

3.2. The influence of albedo and height above ground to produced energy

Results in Table 2 and Figure 2 imply that change in geographic location is still the most important variable. The produced energy of Yinchuan under the situation albedo 20% and height above ground 0.5m is much higher than that of Beijing under the situation albedo 80% and height above ground 2.5m. There is no doubt that the increasing height above ground and albedo have a positive impact on produced energy. When the albedo is low to 20%, the produced energy increases slowly with the increase in the height above the ground, when the albedo increases to over 50%, the produced energy tends to be flat with the rapid increase in the height above the ground. When adjusting parameters of the height and albedo, the increase in produced energy of the module is mainly achieved through the gain of energy generation on the back, which depends on the almost linear product of the bifacility
factor of the module and the irradiance on the back. As the bifacility factor of the module is 65%. Take Yinchuan as an example, when the ground albedo is low to 20%, the effective irradiation received from the back side is low to 92 kWh/m². Even if the ground clearance is increased, the actual energy gain of the module is limited, so the curve is smooth. But when the ground albedo is increased to 50% above, the irradiation on the back side of the module is greatly increased. And the change in the height above the ground will significantly affect the trend of the curve. When the height above the ground reaches a certain height of 2.0m, the effective irradiation on the back has basically reached saturation, so the curve tends to be flat (Figure 3). Similarly, the energy increase with ground albedo from 20% to 50% is higher than that with ground albedo from 50% to 80%, but the increase curve gradually increases with the increasing height. Meanwhile the lower the irradiation, the greater the energy increase.

Figure 2. The relationship between produced energy and height above ground (a:Beijing, b:Yinchuan, c:Guangzhou).
Figure 3. The relationship between global incident on rear side and height above ground of Yinchuan.

Table 2. The produced energy compared with different location, albedo and height above grounda.

| Location    | Beijing | Yinchuan | Guangzhou |
|-------------|---------|----------|------------|
| Albedo      | Height above ground (m) | Produced energy (MWh/year) | Global incident rear side (kWh/m2) | Produced energy (MWh/year) | Global incident rear side (kWh/m2) | Produced energy (MWh/year) | Global incident rear side (kWh/m2) |
| 20%         | 0.5     | 70.5     | 87.0       | 88.1       | 92.0       | 52.7       | 86.0       |
|             | 1.0     | 70.9     | 104.0      | 88.6       | 113.0      | 53.0       | 101.0      |
|             | 1.5     | 71.2     | 115.0      | 88.9       | 126.0      | 53.3       | 111.0      |
|             | 2.0     | 71.3     | 120.0      | 89.0       | 133.0      | 53.5       | 117.0      |
|             | 2.5     | 71.4     | 122.0      | 89.1       | 136.0      | 53.5       | 120.0      |
| 50%         | 0.5     | 73.5     | 191.0      | 91.3       | 210.0      | 55.5       | 186.0      |
|             | 1.0     | 74.5     | 234.0      | 92.5       | 264.0      | 56.4       | 224.0      |
|             | 1.5     | 75.2     | 259.0      | 93.2       | 295.0      | 57.0       | 250.0      |
|             | 2.0     | 75.5     | 273.0      | 93.6       | 312.0      | 57.4       | 264.0      |
|             | 2.5     | 75.7     | 279.0      | 93.7       | 320.0      | 57.6       | 271.0      |
| 80%         | 0.5     | 76.4     | 295.0      | 94.4       | 329.0      | 58.3       | 286.0      |
|             | 1.0     | 78.1     | 363.0      | 96.2       | 414.0      | 59.7       | 347.0      |
|             | 1.5     | 79.1     | 404.0      | 97.3       | 464.0      | 60.8       | 388.0      |
|             | 2.0     | 79.6     | 425.0      | 97.8       | 491.0      | 61.3       | 411.0      |
|             | 2.5     | 79.9     | 436.0      | 98.0       | 504.0      | 61.6       | 422.0      |

a. The value of sheds spacing is 6.6m. The tilt is 30.0°.

4. Conclusions
Energy simulation analysis is based on Beijing, Yinchuan and Guangzhou via PVsyst software. The effect of geographical site, installation tilt, ground albedo and height above ground to energy produced is compared respectively. Optimizing the project location and increasing the global irradiation is the most direct and effective way to increase the produced energy, because the way of adjusting the installation tilt, ground albedo and height above high is limited to increase the irradiance. Respectively, the modules generate more power when the installation tilt is close to latitude as the effective received irradiance is highest. The higher the albedo of the ground, the greater the impact of tilt changes on produced energy. Meanwhile, the increasing height above ground promotes to the higher energy. And
the produced energy is more sensitive to the variable value of ground albedo compared with height. When based on the same height above ground or tilt, the energy increase with ground albedo from 20% to 50% is higher than that with ground albedo from 50% to 80%.

References
[1] Chen J-Y, Huang C-H, Gilmore J, Roesch J, Zhu W 2010 LCOE reduction for megawatts PV system using 500kW transformerless inverter 2010 IEEE Energy Conversion Congress and Exposition 392
[2] Braun S, Hahn G, Nissler R, Pönischb C, Habermann D 2013 The multi-busbar design: an overview Energy Procedia 43 86
[3] Braun S, Nissler R, Ebert C, Habermann D, Hahn G 2014 High efficiency multi-busbar solar cells and modules IEEE Journal of Photovoltaics 4 1
[4] Huang HB, Lv J, Wang LC, Wang JB, Zhu WC, Mandrell J, Sullivan J, Adibi B, Smith C, Laine H, Savin H 2015 An extendible beyond 20% efficiency cost-efficient bifacial cell using boron & phosphorus implantation technology and its prospects for the future production 2015 IEEE 42nd Photovoltaic Specialist Conference
[5] Eisenberg Y, Kreinin L, Bordin N, Eisenberg N, Grigorieva G, Kagan M, Hava S 2016 Effective surface recombination of p+-layer in p-type silicon PERT bifacial cell 32nd European Photovoltaic Solar Energy Conference and Exhibition 711
[6] Janssen G. J. M, Tool K. C. J, Kossen E. J, Van Aken B. B, Carr A. J, & Romijn I. G 2017 Aspects of bifacial cell efficiency Energy Procedia 124 76
[7] Dao VA, Kim S, Lee Y, Kim S, Park J, Ahn S, Yi J 2013 High-efficiency heterojunction with intrinsic thin-layer solar cells: a review Current Photovoltaic Research 1 2
[8] Qian JD, Thomson A, Blakers A, Ernst M 2018 Comparison of half-cell and full-cell module hotspot-induced temperature by simulation IEEE Journal of Photovoltaics 8 3
[9] Rabanal-Arabac J, Rudolph D, Ullmann I, Halm A, Schneider A, Fischer T 2017 Cell-to-module conversion loss simulation for shingled-cell concept 33rd European Photovoltaic Solar Energy Conference and Exhibition 178
[10] Klasen N, Mondon A, Kraft A, Eitner U 2017 Shingled Cell Interconnection: A New Generation of Bifacial PV-Modules 7th Workshop on Metallization and Interconnection for Crystalline Silicon Solar Cells
[11] Fischer M, Woodhouse M, Herritsch S, Trube J 2020 International technology roadmap for photovoltaic (ITRPV) VDMA eleventh edition
[12] Murugavel V, Manikandan S 2020 Performance evaluation of bifacial and monofacial modules in vertical and latitude mounting at south India using PVsyst 3rd International conference on advances in mechanical engineering
[13] Sun YL, Chen RR, Chen SM 2019 Study on numerical simulation and optimization of output characteristics of bifacial PV module based on outdoor empirical tests Renewable Energy Resources 8
[14] Liang TS, Pravettoni M, Deline C et al 2019 A review of crystalline silicon bifacial photovoltaic performance characterisation and simulation Energy & Environment Science 12 116
[15] Kalbasi R, Jahangiri M, Nariman A, Yari M 2019 Optimal Design and Parametric Assessment of Grid-Connected Solar Power Plants in Iran, a Review Journal of Solar Energy Research 4 142