Performance Analysis of the BIPV of an Industrial Park in Wuhan

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Abstract: The performance of BIPV system is a crucial factor for its development. This paper chooses PV arrays installed on an industrial park buildings in Wuhan as a research object. The performance of PV array has been investigated at different tilt angles and orientations on the meteorological conditions of Wuhan. The performance of the amorphous silicon BIPV system and that of the polysilicon BIPV system are presented. The two BIPV systems are both 30 kW, with a tilt angle of 20° and facing south. The performance analysis shows that average monthly output energy of the polysilicon system and that of the amorphous silicon system are 2440.85 kWh and 2209.14 kWh respectively. The performance of amorphous silicon BIPV system is better in May, June, July and August. The maximum monthly output energy can be obtained in August (3768 kWh and 3308 kWh). For the amorphous silicon BIPV systems facing south and with different tilt angles of 20° and 10°, more output energy can be obtained from the amorphous silicon BIPV system with a tilt angle of 20°. The performance of the amorphous silicon BIPV systems oriented facing south with a tilt angle of 10° and that of the amorphous silicon BIPV systems oriented facing north with the same tilt angle are also analyzed respectively in this paper. These analyzes will provide a reference for the development of BIPV in Wuhan.

1. Introduction

With global environmental concerns and escalating demands for energy, renewable energy is becoming increasingly important. One of the biggest energy consumers is the buildings. According to the survey of International Energy Agency, building energy consumption accounts for 32% of the world's energy consumption [1]. So the concept of zero energy building (ZEB) is an attractive approach to reduce the energy requirement of buildings leading to a more sustainable society [2], [3]. To date, solar energy is the most abundant inexhaustible and clean of all the renewable energy resources. Among the ways to utilize the solar energy, BIPV is the most promising way [4].

In BIPV systems, some traditional building materials are replaced by photovoltaic materials, such as the roofs, skylights or facades [5]. The BIPV has the advantage of lower cost by reducing normal construction costs of building materials and labor for parts of the building replaced by BIPV modules [5]. The BIPV system is considered as a functional part of the building structure and is architecturally integrated into the building’s design [6]. The most important part of the system is the photovoltaic modules, which can produce electricity [7], [8]. When in the absence of other energy generation
systems, the BIPV can balance the energy demand of the building [9]. Wuhan is a fast-growing city and the area of buildings is very large. The solar energy is abundant in Wuhan. All these provide good conditions for the development of BIPV. There are some investigations concerning the similar topics but few are conducted in Wuhan[10]. For this reason, an experimental study of the BIPV systems in Wuhan was presented. This paper studied the performances of different BIPV systems. The BIPV systems include systems with different tilt angles and orientations, an amorphous silicon BIPV system and a polysilicon BIPV system. Besides producing energy, all the PV arrays replace the traditional roof-tile as actual parts of the buildings.

2. The BIPV system

Wuhan is located at latitude 30°N and has a subtropical monsoon humid climate. The rainfall and sunshine in Wuhan is abundant. It has an annual average temperature of 15.8°C-17.5°C. The summer is hot and winter is cold. July and August is the hottest month with an average temperature of 28.7°C while January is the coldest with an average of 0.4°C. The summer is long for 135 days. The annual average sunshine time is up to 2000 hours and annual average frost-free period is up to 240 days. The solar elevation angle is up to 83°.

In this paper, three groups of BIPV systems are analyzed and are all nominal 30 kWp. The BIPV systems are composed of modules of 90 Wp. The modules are arranged in six strings. Fig.1 shows the electrical diagram of the modules of the BIPV systems. The BIPV systems run well and are in the same location, an industrial park in Wuhan. The first group are polysilicon BIPV system and amorphous silicon BIPV system oriented facing south with a tilt angle of 20°. The second group are the amorphous silicon BIPV systems oriented facing south with different tilt angles of 10° and 20°. The third group are the amorphous silicon BIPV systems with a tilt angle of 10° oriented facing south and north respectively. The three groups are showed to analyze the performance of the systems with different material, angles and orientations. All the systems are grid-connected by the same inverter. The monthly power output was measured and recorded in 2015 by data collection system automatically.

![Figure 1. Electrical diagram of the modules of the BIPV systems.](image)

3. Results and discussion

3.1 The performance of polysilicon BIPV system and amorphous silicon BIPV system

The monthly power output of the two BIPV systems is shown in Fig. 2. The maximum values of monthly output energy of the two BIPV systems can both be obtained in August (3308kWh and 3768kWh), in which the solar irradiance are the highest. The average monthly output energy of polysilicon BIPV system is 2440.85kWh, while that of the amorphous silicon BIPV system is 2209.14kWh, the latter is 90.5% of the former. The performance of the two BIPV systems is the best in summer. From May to August the performance of the amorphous silicon BIPV system is better than that of the polysilicon BIPV system. This is because that the temperature is high in the four months and that the temperature coefficient of polysilicon is larger than that of amorphous silicon. The energy conversion efficiency will become lower with the increase of the temperature. In other months, the temperature is not that high and the influence of temperature is reduced, so the performance of the
polysilicon BIPV system is better. In Spring, the performance of the systems becomes better and better with the increasing irradiance. In Autumn, the monthly output energy is reduced month by month with the decreasing of the irradiance. In Winter, because of the lower temperature, irradiance and snow, the output energy is the least of the four seasons. This will provide a reference for the design and investment of the BIPV systems.

Figure 2. Monthly energy production from polysilicon BIPV system and amorphous silicon BIPV system

3.2. The performance of BIPV systems with different title angles

The performance of the BIPV systems with different title angles is showed in Fig.3. The maximum monthly energy production of the two BIPV systems both can be obtained in August, 3768 kWh and 3540 kWh respectively. It can be found that the performance of BIPV system with a tilt angle of 20° is better than that of BIPV system with a tilt angle of 10°. This is because that Wuhan is located at latitude 30° and the theoretical optimum tilt angle is about 30° [5]. The closer to the optimum tilt angle, the more the direct radiation on the photovoltaic module is. On general sunny day, the direct radiation is the main factor to the energy output of the system. According to the weather forecast for Wuhan in 2015, many days are rainy, cloudy or snowy each month and in this climate, the irradiance is mostly of diffuse nature due to the scattering of sunlight by the predominantly overcast sky. Thus the impact of the tilt angles on the performance of the BIPV systems is reduced. The energy production of the two systems is similar and has little difference. In many cases, the design of BIPV should not only consider the amount of power generation, but also take the beauty, strength and lots of other factors into account. In general, the slope of the tile roof should not be less than 20%.

Figure 3. Monthly energy production from BIPV systems with different title angles
3.3. The performance of BIPV systems with different orientations

Fig. 4 shows the energy production of the BIPV systems with different orientations. The performance of the BIPV system facing south is better than that of the BIPV system facing north. In order to analyze the performance of the two BIPV systems with different orientations, the energy performance ratio defined as the ratio of the monthly output energy of the BIPV system oriented facing north to that of the BIPV system oriented facing south is shown in the Fig.5. The performance of the BIPV systems is the best in the August (4714kWh and 3743kWh) and the difference between the two BIPV systems is bigger in May, June, July and August than other months. This is because that the irradiance in August is the highest in the year of 2015 and that the direct irradiance in the four months is higher than that in other months.

![Figure 4. Monthly energy production from BIPV systems with different orientations](image1)

![Figure 5. The ratio of the monthly output energy of the BIPV system oriented facing north to the that of the BIPV system oriented facing south](image2)

4. Conclusions

The presented performance of BIPV systems is a viable and reliable contributor in achieving the zero-energy target for the building in Wuhan. After analyzing the performance of the BIPV systems, the following conclusions can be drawn.

1. When the BIPV systems are both with a tilt angle of 20° and facing south, the monthly energy production of the amorphous silicon BIPV system is more than that of polysilicon BIPV system from May to August. In other months, the performance of the polysilicon BIPV system is better. In summer, the energy production of the two systems is the most and that is the least in winter.

2. The performance of amorphous silicon BIPV system with a tilt angle of 20° is better than that of amorphous silicon BIPV system with a tilt angle of 10°. The difference of the yearly energy production of the two BIPV systems is up to 2514kWh.
3. The performance of the BIPV system oriented facing south is better than that of the BIPV system oriented facing north. The performance of the BIPV systems is the best in the August and the difference between the two BIPV systems is bigger in May, June, July and August than other months. The difference of the yearly energy production of the two BIPV systems is up to 5958 kWh.

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6. References

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