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The Power Comparison of Photovoltaic Modules Different Types

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Abstract. The article presents research results obtained from bifacial and monofacial monocrystalline photovoltaic modules. Identification of power changes was performed for different tilt angles 25° (installed on the building roof). The aim of experimental research was also monitoring of external factors (temperature of photovoltaic module, wind velocity and intensity of solar radiation) which have influence on power balance of photovoltaic system. Finally, computational simulation for identification of photovoltaic system power balance changes for bifacial photovoltaic modules installed on roof with different black and white surface was applied. The measured data were collected from solar invertors FRONIUS IG. The external factors were measured by pyranometer CMP 11 and anemometer A100R. From obtained power graphical relations is clear that the bifacial modules had better power balance than the monofacial and its energy production strongly depend on roof surface material reflection coefficient. For the data comparison was applied correlation analysis on the 2 dimensional graphical relations.

INTRODUCTION

Monitoring of PV systems parameters is important for the PV energy balance detection. The operation parameters were investigated by authors [1, 2]. Solar power generation has proven to be one of the most attractive option for electrical energy production in grid-connected and distributed modes [3, 4]. The possibilities of photovoltaic system application were described in Slovak literature [5–7] and by foreign authors [8, 9]. Monitoring of PV systems parameters is important for the PV energy balance detection. It is known from the sources [8–14] that the power, efficiency and quantity of electricity generated by photovoltaic system depend on many external factors such as: intensity of solar radiation, ambient temperature, wind speed, temperature of PV modules, reflectivity of PV modules surfaces and reflectivity of the roof or the building wall surfaces where are PV modules installed and it also depends on internal factors which are determined by materials and construction of PV modules, angle of construction orientation to the cardinal directions, tilt angle of the PV module etc. The aim of the presented research was power comparison of bifacial and monofacial monocrystalline PV modules with tilt angle 25°.

MATERIAL AND METHODS

The measurements were done on solar power stations in the Czech Republic, which are installed on the roof of the Faculty of Education, Masaryk University. The whole area of the photovoltaic system is 337.2 m^2. Orientation of this photovoltaic power plant is SW. The PV modules have to be installed with the tilt angle of 25°, which is not optimal from the theoretical point of view (in theory [15] ideal tilt angle for this location is 35°) because the building is important architectonical monument. The photovoltaic system is divided into two sections. The first section of PV system consisting of 288 monofacial monocrystaline panels SI 72-110 (Solartec, Czech Republic). The total power output of this section is 30 kWp. The second section of the PV system has total power 5 kWp and is equipped by new type of bifacial monocrystalline PV modules SBI2G 72-90BR (Solartec, Czech Republic) (Figure 1). The bifacial modules produce solar power from both sides of the module.

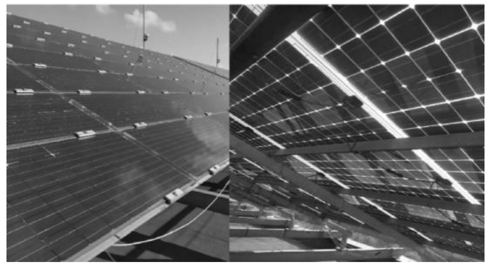

FIGURE 1. Bifacial PV modules SBI2G 72-90BR-MC

For converting DC voltage that is supplied by photovoltaic cells, for AC voltage 230 V with frequency 50 Hz serve 5 voltage converters type FRONIUS IG40 (Fronius, Austria) and 3 voltage converters type FRONIUS IG60HV (Fronius, Austria), efficiency of these converters is 94.3%. The whole photovoltaic system is connected to the main switchboard to the internal power network of the faculty. This makes it possible to supply The generated electricity is supplied to the grid. The solar radiation is measured with pyranometer CMP11 (Kipp&Zonen, Netherlands) and wind velocity is measured by anemometer A100R (Campbell Scientific, United Kingdom).

RESULTS AND DISCUSSION

The power of different types PV modules was compared during the one-year period. Because of huge data sets which were obtained from the experiments, the data selecting procedure was applied on the data files. For presentation of results were chosen model days for every month. Every evaluated day parameters as ambient temperature, relative air humidity, wind speed, intensity of solar radiation were compared with the monthly average for each point of graphical dependencies. The model day was extracted from the data obtained for every season (e.g., autumn) by comparison of experimental day data and the average values were calculated for every time point. Correlation analysis was applied on the experimental data. The model day of the season had a high degree of correlation with the average monthly parameters in terms of statistics. These days were without extreme cloudiness changes [6]. For power evaluation of PV system in model day was selected the time range from 9 a.m. to 4 p.m. when the solar radiation culminates. The power of 30 kWp section with monofacial monocrystalline PV module was recorded with 6 voltage converters and each converter had power 5 kWp. For this section was calculated the average value of power from all converters.

The next part of research was focused on the processing and comparison of powers obtained from bifacial and monofacial PV modules with the same tilt angle 25°. The average values of power were detected by data processing in MS Excel and Matlab 2015b. The selected results are presented in the (Figure 2) where are shown the time relations of power for the different types of PV modules in June and December. From complex power balance evaluation is evident that the monocrystalline bifacial PV modules had 7.6% higher average power balance than the classic monocrystalline PV modules during the year. Monocrystalline bifacial glazing PV modules can also use reflected solar radiation from the roof surface where they are installed. The lowest percentage difference of power 1.4% was found in March. Percentage differences higher than 10% were identified in months from August to December.

All dependencies were statistically processed and the results of correlation analysis for all mentioned measured parameters (intensity of solar radiation, power ambient temperature, wind speed, temperature of PV modules) were summarized. Based on the correlation analysis results is clear that the higher correlation degree 0.91 is between the PV module temperature and intensity of solar radiation. The lowest correlation coefficient 0.30 was found for relation between the PV module temperature and the wind velocity. Second part of the correlation analysis was focused on PV module power. PV module power is most affected by global radiation (35.94%) and PV module temperature (32.70%). The effect of wind speed and ambient temperature on PV module power is very similar, approximately 15%. Presented results are in good agreement with facts in the literature [16].

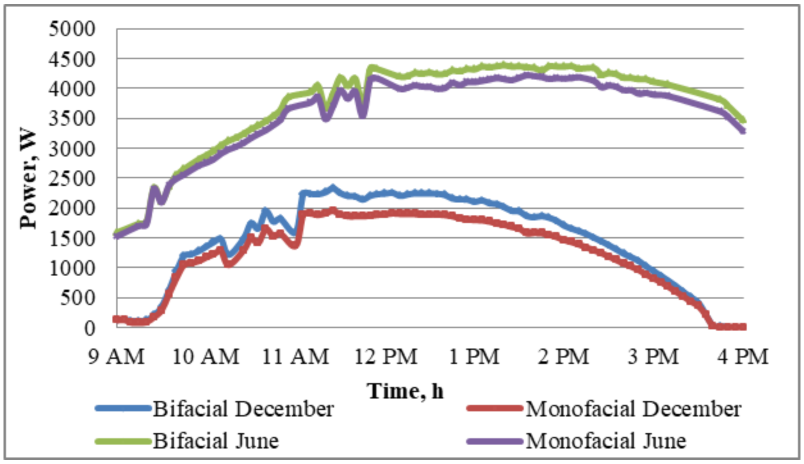

FIGURE 2. Power of PV modules different types in month June and December

In the next part, the influence of material surface under the PV modules was simulated by software Mathlab 2015b. PV solar power stations on the roof of the Faculty of Education have on the ground black asphalt board IPA, so the main advantage of bifacial photovoltaic modules was not used in the full range because of low material reflexivity coefficient – albedo. Ideal surface for installation of bifacial PV modules should have maximal value of albedo. For comparison of albedo influence was performed computer simulation for material with higher value of albedo (white facade color – Baumit SilikonTop under the bifacial PV modules). The results of simulation for May are shown on the (Figure 3).

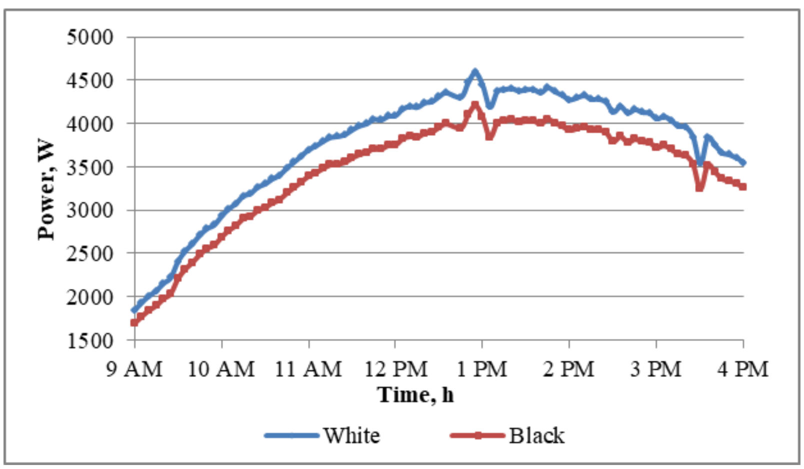

FIGURE 3. Simulation of PV system power with white surface under the bifacial PV modules during model day in May

CONCLUSION

From the presented results is clear that the position of PV module installation represented by tilt angle has significant influence on the PV module and PV system power. By the data analysis was found that bifacial monocrystalline photovoltaic modules have higher positive power balance during the year, but their performance is influenced by many external and internal operational aspects. The most important are external factors mainly weather conditions (maximum influence have intensity of solar radiation) and the reflexivity of material surface under the PV modules. Experimental results point to the fact that the surface albedo can positively affect the performance of the PV system, especially the positive effect on power balance was determined for materials with high reflexivity coefficient.

ACKNOWLEDGMENTS

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