An Effect of Photovoltaic (PV) Arrangement on Performance of Small-scale Solar Energy System

Sudarsono Sudarsono[1*], *Toto* Rusianto[1], and *Samuel* Kristiyama[2]

[1]Department of Mechanical Engineering, Faculty of Industrial Technology, Institut Sains & Teknologi AKPRIND, Indonesia
[2]Department of Electrical Engineering, Faculty of Industrial Technology, Institut Sains & Teknologi AKPRIND, Indonesia

Abstract. Nowadays, solar energy got increasing attention worldwide. As a matter of fact, in renewable sources, solar power contribution is so high when compared with other sources. The present study aims to figure out an effect of photovoltaic (PV) arrangement on the performance of 150 W and 200 W solar energy conversion system. Three PV configurations, i.e standalone 150 W (model I), 100 W + 50 W (model II), and 3 x 50 W (model III) are tested for the 150 W solar energy system and three other PV configurations, i.e. 150 W + 50 W (model IV), 4 x 50 W (model V), and 2 x 100 W (model VI) are investigated for 200 W solar energy system. The results show that model VI is able to generate an average output power of about 116.44 W which means that the model has an efficiency of 58.22% with respect to the design capacity of the PV.

1 Introduction

Due to the depletion of conventional fuel and also due to increasing global warming in last several years, the search of alternative and renewable energy increases remarkably worldwide. Many sources of alternative energy have been explored to substitute a conventional source of energy by numerous researchers. Solar energy, one of the most promising alternative energy sources, is got increasing attention nowadays. In the utilization of renewable energy, solar power contribution is higher when compared with other sources [1]. Commonly, solar energy is converted into electrical energy. In fact that solar energy is abundant and requires low costs conversion technology, making solar energy extremely popular [2]. Solar energy has been converted into another form of energy and used for rural electrification [3], heat source [4.5], refrigeration and cooling [6, 7], industrial processing [8], and many other utilizations.

Solar energy conversion system requires basic components of solar collector, battery, and inverter. Solar collector adsorbs and converts solar radiation into electric energy. Solar panel compromise of photo voltaic (PV) cell which utilize photon from sun light into electrical energy [2]. The electric energy is stored in the battery. DC current from battery is converted

* Corresponding author: sudarsono1574@akprind.ac.id

into AC current by inverter. Since conversion of solar radiation into electrical energy occurs in PV cell, conversion efficiency of the solar energy system is significantly affected by performance of the PV cell. Various work on investigation of PV cell performance have been conducted worldwide. Gupta *et al.* [1] studied experimentally a combined transparent solar panel and large Fresnel lens concentrator-based hybrid PV/thermal sunlight harvesting system. Altuntepe *et al*. [9] used hybrid transparent conductive electrode structure for solar cell application. Ghoshal & Gaidhane [10] analyzed a hybrid tandem solar cell using neural network. Liang, *et al*. [11] conducted experimental analysis of the concentrated crystalline silicon solar cell-slicing cell. IoT based monitoring system for solar energy system has been also reported by Bhau *et al*. [2]. Meanwhile, Mishra, *et al*. [12] proposed an expression for the electrical efficiency of photovoltaic modules in different photovoltaic thermal (PVT) configurations.

To increase performance of the solar energy system, many optimization efforts have been conducted. Merino *et al.* [13] optimized energy distribution in solar panel array configurations by graphs and Minkowski's paths. Zhong & Tong [14] performed optimization on spatial layout for solar photovoltaic (PV) panel installation. Wang *et al*. [15] worked on optimization of the areas of solar collectors and photovoltaic panels in liquid desiccant air-conditioning systems using solar energy in isolated low-latitude islands. Oon *et al*. [16] reported an optimization study of solar farm layout for concentrator photovoltaic system on azimuth-elevation sun-tracker. Other works in enhancing performance of the solar energy system are performed by modification of solar cells with antireflection coatings [17] and by using thermal control water spraying cooling in polycrystalline solar panel [18].

Although many works have been reported in the PV cell of solar energy system, none of those work analyzed an effect of solar panel arrangement so far. Thus, the present work aims to figure out an effect of photovoltaic (PV) arrangement on performance of 150 W and 200 W solar system. Three PV configurations, i.e standalone 150 W (Model I), 100 W + 50 W (Model II), and 3 x 50 W (Model III) are tested for the 150 W solar system and three other PV configurations, i.e. 150 W + 50 W (Model IV), 4 x 50 W (Model V), and 2 x 100 W (Model VI) are investigated for 200 W solar system.

2 Materials and Methods

Figure 1 shows schematic diagram of an experimental setup of the small-scale solar energy system in the present work. The system is constructed by solar panel (PV), solar charger controller MPPT, Battery 12V/100Ah, Inverter 1000 W, AC load, and MCBs. The PV absorbs solar irradiant and converts it into electrical energy. Solar charger controller control the voltage and current to the battery. The inverter 1000 W is used to convert DC to AC prior to be supplied to the AC load of LED lamp. In the present work, an effect of three different PV arrangements on performance of 150 W solar energy system and three other different configurations are tested for 200 W solar energy system. The PV arrangements of the present work are shown in Table 1.

Output voltage and current from each model of PV arrangement, temperature, and solar irradiant are measured every hour from 9.00 am to 3.00 pm within 5 days. The performance of the PV model arrangement is evaluated in term of power output and calculated using Eq. (1).

$$P = V \times I \qquad (1)$$

where V is the output voltage (Volt) and I is the output current (Ampere) of the PV arrangement models.

 https://doi.org/10.1051/e3sconf/202235901002

Table 1. PV arrangement model in the present work

Capacity of Solar System	PV Arrangement	Description
150 W	Model I	150 W
	Model II	100 W + 50 W
	Model III	3 x 50 W
200 W	Model IV	150 W + 50 W
	Model V	4 x 50 W
	Model VI	2 x 100 W

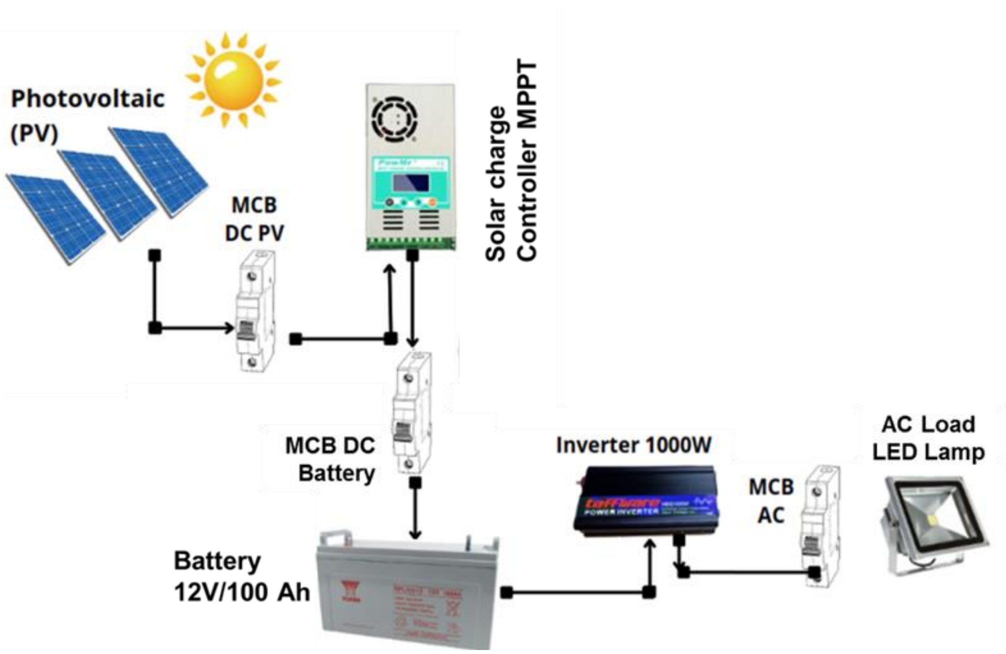

Fig. 1. Schematic diagram of the experimental setup

3 Results and Discussion

Figure 2 displays temperature profile from 9.00 am to 15.00 pm within 5 experimental days. The graph in Fig. 2 indicates that temperature increases from 9.00 am to 13.00 pm. After reaching maximum temperature at about 13.00 pm, the temperature declines. This trend of the temperature profile almost similar during those days. The graph also shows that the highest temperature occurs in 4^{th} day.

 https://doi.org/10.1051/e3sconf/202235901002

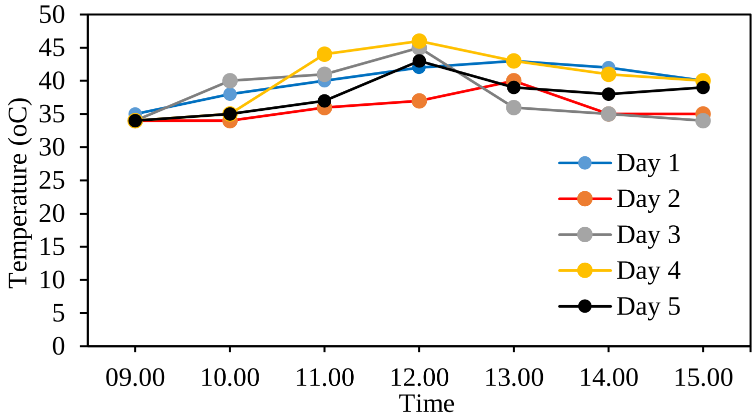

Fig. 2. Temperature profile during experimental work

Figure 3 and Figure 4 present an effect of PV arrangement on output voltage and output current of the 150 W and 200 W solar energy system. Three PV arrangements investigated in the present work are model I (standalone 150 W PV), model II (100 W + 50 W PV), model III (3x50 W PV), model IV (150 W + 50 W), model V (4 x 50 W), and model VI (2 x 100 W). For particular solar irradiant impinging to the PV, the output voltage and current steps up as increasing solar irradiant for all models as shown in Fig. 3 and Fig. 4. From Fig. 3, the output voltage of model VI is the highest at irradiant above 4383 W. Meanwhile, the highest output current for particular solar irradiant is observed on model I.

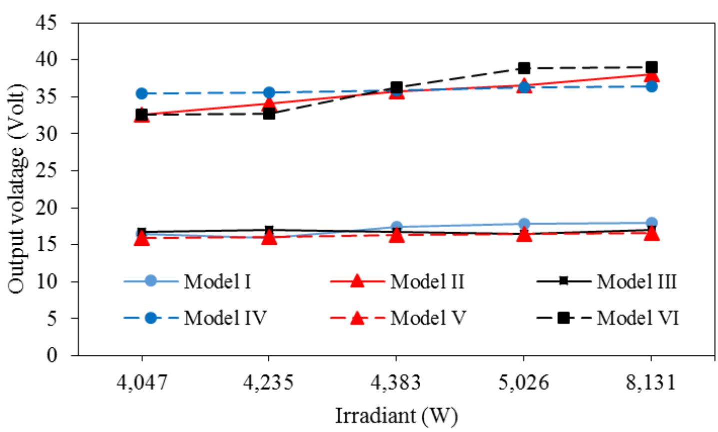

Fig. 3. Output voltage

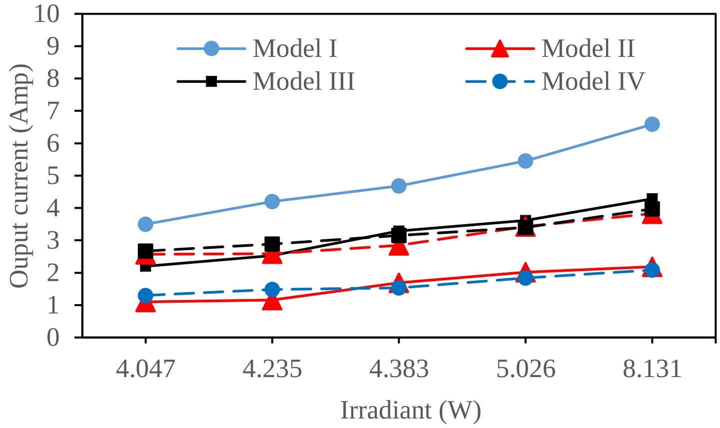

Fig. 4. Output current

The output voltage and output current data are used to obtain output power of the model using Eq. (1) and the results are plotted in Fig. 5. The graph reveals that the output power of the PV is proportional to the solar irradiant. The output power rises up as increasing solar irradiant to the PV. From Figure 5, it can be stated that the model I is the most suitable arrangement for 150 W solar energy system and model VI is the best arrangement for 200 W solar energy system. Meanwhile, Figure 6 shows an average output power and efficiency of the models. In average, model I, II, III, IV, V, and VI generate actual power of 81.35 W, 54,64 W, 51.02 W, 59.31 W, 49.61 W, and 116.44 W, accordingly. Comparing between an actual average output power and the PV design capacity, the model VI gives the highest efficiency, i.e. 58.22%. On the other hand, model V has the lowest efficiency in the present work.

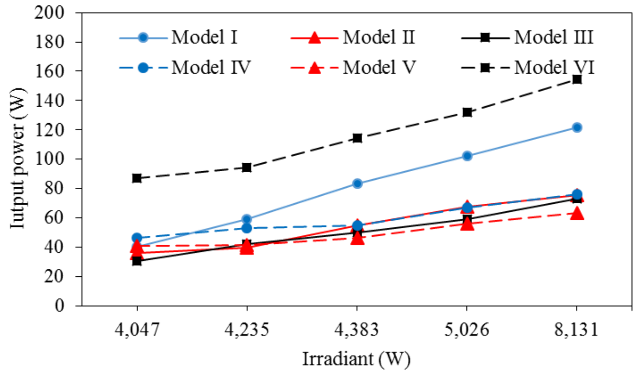

Fig. 5. Output power.

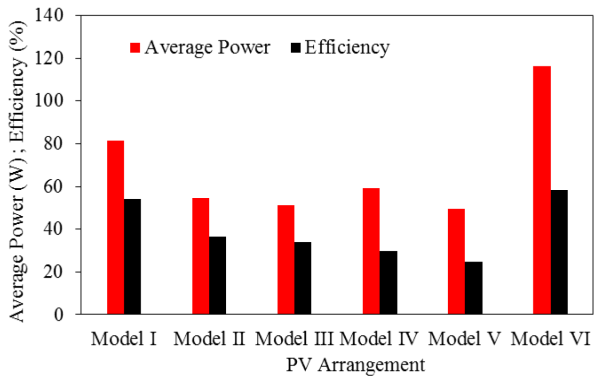

Fig. 6. Average power and efficiency

4 Conclusion

The investigation an effect of PV arrangement on performance of the 150 W and 200 W solar energy systems has been carried out in the present work. It can be concluded that the model VI (2 x 100 W) has the best performance in the present work. The model VI able to generate an average actual output power about 116.44 W which means that the model has an efficiency of 58.22% respect to the design capacity of the PV

The authors sincerely thank to DRPM-RISTEK/BRIN, Kementerian Riset dan Teknologi/Badan Riset dan Inovasi Nasional (Ministry of Research and Technology/Board of National Research and Innovation) of Republic of Indonesia for the financial support through the scheme of Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT) year of 2021.

References

1. M. Gupta, A.K. Dubey, V. Kumar, D.S. Mehta, “Experimental study of combined transparent solar panel and large Fresnel lens concentrator based hybrid PV/thermal sunlight harvesting system,” *Energy for Sustainable Development*, vol. 63, pp. 33–40 (2021), doi: https://doi.org/10.1016/j.esd.2021.05.008
2. G.V. Bhau, R.G. Deshmukh, T.R Kumar, S. Chowdhury, Y. Sesharao, Y. Abilmazhinov, “IoT based solar energy monitoring system” *Materials Today: Proceedings* (2021), doi: https://doi.org/10.1016/j.matpr.2021.07.364
3. B.P. Koirala, B. Ortiz, A. Modi, J. Mathur, N. Kafle. “Solar lighting systems delivery models for rural areas in developing countries”. In: Schäfer M, Kebir N, Philipp D, (Eds.), Micro Perspectives for Decentralized Energy Supply, Berlin, Germany; 268–278 (2011)
4. M.S. Guney. “Solar power and application methods”. *Renew Sustain Energy Rev*; 57:776–85 (2016)
5. G. Manente. “High performance integrated solar combined cycles with minimum modifications to the combined cycle power plant design”. *Energy Convers Manag*; 111:186–97 (2016)
6. A. Modi, A. Chaudhuri, B. Vijay B, J. Mathur. “Performance analysis of a solar photovoltaic operated domestic refrigerator”. *Appl Energy*;86(12):2583 (2009)
7. I. Sarbu, C. Sebarchievici. “Review of solar refrigeration and cooling systems” (2013)
8. EA-ETSAP, IRENA. “Solar heat for industrial processes - Technology brief”. *Tech. Rep.* (2015)

9. A. Altuntepe, M.A. Olgar, S. Erkan, O. Hasret, A.E. Keçeci, G. Kökbudak, R. Zan, R. "Hybrid transparent conductive electrode structure for solar cell application." *Renewable Energy*, vol. 180, pp. 178–185 (2021), doi: https://doi.org/10.1016/j.renene.2021.08.061
10. M.N. Ghoshal and V.H. Gaidhane, "Analysis of hybrid tandem solar cell using neural network," *Materials Today: Proceedings*. doi:10.1016/j.matpr.2021.08.226
11. K. Liang, D. Ai, H. Zhang, Y. Zhao, Y. Zhang, H. Chen, "Experimental performance analysis of the concentrated crystalline silicon solar cell-slicing cell," *Solar Energy*, vol. 224, pp. 1008–1016 (2021), doi: https://doi.org/10.1016/j.solener.2021.06.073
12. R.K. Mishra, R. Tripathi, V.S. Gupta, V.K. Dwivedi, "Expression for the electrical efficiency of photovoltaic modules in different photovoltaic thermal (PVT) configurations. *Materials Today*, vol. 46, no. 13, pp. 754-3760 (2021), doi: https://doi.org/10.1016/j.matpr.2021.02.426
13. S. Merino, F.J. Sánchez, M. Sidrach de Cardona, F. Guzmán, R. Guzmán, J. Martínez, P.J. Sotorrío, "Optimization of energy distribution in solar panel array configurations by graphs and Minkowski's paths." *Applied Mathematics and Computation,* vol. 319, pp. 48–58 (2018), doi: http://dx.doi.org/10.1016/j.amc.2017.01.044
14. Q. Zhong, and D. Tong, "Spatial layout optimization for solar photovoltaic (PV) panel installation." *Renewable Energy*, vol. 150, pp. 1-11 (2020), doi: https://doi.org/10.1016/j.renene.2019.12.099
15. Y. Wang, F. Fan, D. Wang, Y. Liu, Z. Qiu, J. Liu, "Optimization of the areas of solar collectors and photovoltaic panels in liquid desiccant air-conditioning systems using solar energy in isolated low-latitude islands." *Energy*, vol. 198, 117324 (2020), doi: https://doi.org/10.1016/j.energy.2020.117324
16. L.V. Oon, M.H. Tan, C.W. Wong, K.K. Chong, "Optimization study of solar farm layout for concentrator photovoltaic system on azimuth-elevation sun-tracker." *Solar Energy*, vol. 204, pp. 726–737 (2020), doi: https://doi.org/10.1016/j.solener.2020.05.032
17. H.J. El-Khozondar, R.J. El-Khozondar, R. Al Afif, C. Pfeifer, "Modified solar cells with antireflection coatings." *International Journal of Thermofluids*, vol. 11, 100103 (2021), doi: https://doi.org/10.1016/j.ijft.2021.100103
18. O.T. Laseinde and M.D. Ramere, "Efficiency Improvement in polycrystalline solar panel using thermal control water spraying cooling," *Procedia Computer Science*, vol. 180, pp. 239–248 (2021), doi: 10.1016/j.procs.2021.01.161