Impact of the solar energy system with and without reflector on home-scale batik industry

F Mujaahid¹, S Febriyanto¹, R Syahputra¹, K Purwanto¹
¹Department of Electrical Engineering, Universitas Muhammadiyah Yogyakarta, Special Region of Yogyakarta, INDONESIA

Abstract - Harvesting energy from solar has been growing significantly in the past decades. It enlarges the utilization of solar system technology, such as a photovoltaic system. Not only in the large-scale application, but also in the home-scale application. Indonesia is known for traditional batik clothing. There is a lot of various batik from different cities in Indonesia, and Yogyakarta is a city that offers authentic batik clothing. This paper reports the utilization of photovoltaic system in home-scale batik industry in Yogyakarta. The objective is to investigate the system whether there will be an extra power generated from the photovoltaic if a reflector is applied to the panel. There are two kinds of reflectors used in this experiment, they are mirror glass and aluminum foil. The experiment was conducted in the daytime where the amount of solar radiation is in the same intensity among three conditions; a system without reflector, with mirror glass reflector, and aluminum foil reflector. The result shows that in average, the system with mirror reflector has produced 15% higher output power compared to the system without the reflector, or 15.77 Watt higher to be precise.

1. Introduction

The availability of renewable energy sources, especially solar energy, is very abundant. The sun is able to provide energy equals to $944 \times 10^6$ TWh annually [1]. According to the data from New Renewable Energy and Energy Conservation (EBTKE), the Ministry of Energy and Mineral Resources, the solar power potential in Yogyakarta is about 996 M [2]. The city is a major tourist attraction and rich in history and culture. Two examples of solar energy application that have been implemented in Yogyakarta are to help the local tourist attraction and to increase the revenue of traditional products.

A 90 KW hybrid power plant and 46 KW solar-wind power plant were installed in Pantai Baru beach and Baron Techno Park respectively, both attractions are in the rural area of Southern part of Yogyakarta [3][4][5]. According to the locals, considering the area where electricity is scarce, these installed power plants is highly needed to supply the electricity to run their business. Besides, since the power plant was installed, the number of visitors has increased.

Another implementation of non-fossil energy is to support the production of batik, traditional clothing, in Desa Wijirejo [6]. Following the previous work of Ramadoni Syahputra in 2016 about the application of green energy for batik production [6], our work analyses the performances of the existing system if the reflectors (mirror and aluminum reflector) were attached to the solar panels.
1.1 Batik Tugiran
Since declared by UNESCO in October 2009 that Indonesian Batik is a Masterpiece of Oral and Intangible Human Heritage, as a part of its recognition, UNESCO emphasized that Indonesia preserves its cultural heritage [7]. Yogyakarta, one of the well-known Batik centers in Indonesia, has Batik industry, which is located in Desa Wijirejo, Pandak District, Bantul Regency. In the production process, besides the main affecting factors such as raw materials and skilled Batik workers, the fact that Batik production is in dire need of electricity supply, especially for lighting in the stamping and wax-resist dyeing process, is also crucial. In addition, water is also needed during coloring and wax removing process so that the water pump is needed in this Batik production process.

1.2 Off-grid solar panels
Batik Tugiran home industry is one of Batik home industries in Wijirejo which can produce 200 to 400 sheets of Batik each month. The productivity must also be supported by the availability of electricity as a support for the production process. This Batik Tugiran home industry has an innovation by installing solar power generation system. The installation of solar panels applied to the Batik home industry is intended for the main energy supply in Batik production process, namely to supply 6 lighting lamps, water pump, and a Batik electric stove. The average power needed for daily use in Batik Tugiran is 147 W for the lighting system that is used for 5.2 hours and 125 W for the water pump that is used twice a day for half an hour. Thus, the total electricity needed to run the production is 891 Wh per day. The current system in the home industry of Batik Tugiran has an off-grid 400 Wp photovoltaic capacity. Table 1 and figure 1 (left) depict the diagram and specifications of this solar panel scheme.

| Parameters | Specifications |
|------------|---------------|
| Solar panel | Yunde P10E36, 8 x 100Wp, divided into two arrays with 400Wp each |
| MPPT       | CMTR-30A, 100W, 30A, 12/24V |
| Battery    | INCOE NS60-46B24R, 7 x 12V/45Ah |
| Inverter   | SUOER FPC-1000A, Pure sinewave 1000W |

![Figure 1. Block diagram of PV scheme in Batik Tugiran, left: before reflectors were applied, right: after reflectors were applied](image)
Another expectation in the installation of solar panels is that fewer production costs are incurred and do not depend on the supply of PLN (state-owned company for electricity distribution). So that when there is a blackout, the Batik production process is not disturbed. That solar panel installation must also be optimized so that the power produced is able to meet the electricity needs of Batik production. That optimization attempt is by installing reflectors to reflect sunlight radiation, thus more solar radiation can be converted into electricity by solar panels. This is expected to increase the output power of solar panels.

2. Methodology
In Figure 1 (right), it explains the working scheme of PLTS in Batik Tugiran home industry starting from PV to being able to be used by AC loads. The PLTS used in Batik Tugiran home industry is an off-grid, and thus does not connected to the PLN national grid system. In this home industry, there are two PLTS groups, each of which has a 400-watt peak capacity, bringing a total of 800-watt peak capacity.

The specifications of each solar cell module are using YUNDE brand with a power capacity of a 100-watt peak. A maximum working voltage/ampere could reach to 18.05V/5.54A during the charging condition or when the load is being connected. The batteries used are 7 lead-acid batteries (INCOE brand) which have a capacity of 45 Ah and a voltage of 12 V each. The solar charge controller used is PWM type with a current rating of 30 A and automatic voltage output of 12 V / 24V. The last component is inverter which is used to change the DC current and voltage from the battery to AC. The pure sine wave inverter type is used with a power of 1000 W. Two DC ammeters are inserted after the solar cell module and battery, respectively. Another ammeter (AC) is placed after the inverter to measure the electricity used by the load.

In this study, one method of optimizing the output power of solar panels is obtained by using a reflector or an object that can reflect sunlight. It is expected that the more sunlight received by the surface of solar panels, the more power will be generated. The reflectors used are made of glass and aluminum foil. The next process was testing solar panels using each of these reflectors. Testing for each of the three conditions; without reflector, with glass reflector, and with aluminum reflector, was carried out for 12 days, namely the first four days without a reflector, the next four days with glass reflector (see Figure 2; left), and the last four days with aluminium reflector (see Figure 2; right).

![Figure 2. The Installation of Glass Reflector (left) and Aluminum Reflector (right) with an Angle of 110° with respect to PV modules](image)

The testing with reflectors was done by attaching a fixed reflector with an angle of 110° with respect to the surface of the solar panel, see Figure 3. This angle is obtained from the previous research in which this number is the most optimal angle to reflect more sunlight to the panels [8].
The testing process was done by observing the voltage and current in all three measuring instruments (ammeters) with changes in every 30 minutes. The first measuring device is on the solar panel output, the second is on the battery leading to the inverter, and the last one is on the inverter output. The observations were conducted from 8 AM to 4 PM for six days on April 19th, 20th, 21st, 22nd, 23rd, 26th, and 27th 2019.

After the test was carried out, the next stage was data collection on all three test conditions. Each test condition must have the same amount of solar radiation every day so that it can be compared between one day and another. The weather conditions and the level of solar radiation will greatly affect the power produced by solar panels. The sun test data were obtained from the NASA application (Power Data Access Viewer) in https://power.larc.nasa.gov/. User needs to set up certain parameters before obtaining the data, see Table 3.

### Table 2. Parameters selection of Power Data Access Viewer

| Parameter                  | Value                                                                 |
|----------------------------|------------------------------------------------------------------------|
| User Community             | SSE-Renewable Energy                                                   |
| Temporal Average           | Daily                                                                  |
| Latitude & Longitude       | -7.8982647 and 110.2987482                                             |
| Time Extent                | January 1st, 2019 to June 30th, 2019                                   |
| Output File Formats        | ASCII                                                                  |
| Output Parameters          | Sizing and Pointing of Solar Panels and for Solar Thermal Applications (all checked) |

After data collection was carried out starting at 08.00 - 16.00 or 8 hours daily, then analysis and comparison of the three experimental conditions were carried out by observing the voltage, current, and power on the solar panel output. In addition, an observation was also carried out on the daily radiation of the sun from NASA’s web sources, so that the results of each experiment and its effect on solar modules performance in Batik Tugiran can be known. The results were then compared, and it was led to the most effective experiment in increasing solar panel performance resulting in more electrical energy sources to meet the electrical energy needs of Batik home industry.

### 3. Results and Discussion

#### 3.1 Solar Radiation

Daily solar radiation is obtained through NASA’s website by inputting the latitude and longitude coordinates of an area on the website. Then, the data, namely solar radiation data in the area for a given period, appear. Daily radiation from 19 to 27 April 2019 showed a value between 4.85 to 6.1 kW-hr/day/m². The weather conditions during data collection tend not to be the same every day,
therefore, the data were retrieved when the radiation is at the same level. Thus, the comparison of each test condition was conducted when it is sunny and at the same solar radiation level.

3.2 V-I-P Outputs

The results show the three measurements of voltage (V), current (I), and power (P). Every measurement has three PV system conditions and tested for two days each; No Reflector (NR) was indicated by black solid/dashed line, Mirror Reflector (MR) was indicated by red solid/dashed line, and Aluminum Reflector (AR) was indicated by blue solid/dashed line.

Figure 4 illustrates the comparison result of voltage and current from the solar modules at its respective time. The red solid/dashed line or the PV system with MR condition shows more steady results compared to the other two conditions. The average voltage/current for every condition are 7.47 V/15.7 A (NR), 6.86 V/17.54 A (MR), and 5.98 V/16.61 (AR).

Figure 5 shows a graph of power output at its respective time. This result is obtained from the calculation of voltage and current. In average, the MR condition has a higher result (120.7 W) compared to NR (104.93 W) and AR (99.74 W). Further detail of solar radiation and V-I-P results are shown in Table 4.

Figure 4. Voltage and current measurement from solar modules output

Figure 5. Power measurement from solar modules output
Table 3. Voltage-Current-Power measurements of solar modules in three conditions; No Reflector (NR1, NR2), Mirror Reflector (MR1, MR2), and Aluminum Reflector (AR1, AR2)

| Voltage measurement (unit = Volt) | Current measurement (unit = Ampere) | Power measurement (unit = Watt) |
|----------------------------------|-------------------------------------|---------------------------------|
| **System Condition**             | **Radiation (kW-h/d/m²)**           | **DATE**                        |
|                                  |                                     |   19 April                      |
| No Reflector (NR)                | 5.6                                  | 20 April                        |
| Mirror Reflector (MR)            | 5.84                                 | 21 April                        |
| Aluminum Reflector (AR)          | 5.57                                 | 22 April                        |
| No Reflector (NR)                | 5.6                                  | 26 April                        |
| Mirror Reflector (MR)            | 5.84                                 | 27 April                        |
| Aluminum Reflector (AR)          | 5.57                                 |                                |
|                                 | 6.1                                  |                                |
|                                 | 6.1                                  |                                |
|                                 | 6.1                                  |                                |
|                                 | 6.1                                  |                                |
| **Average**                      | 7.47 V                               |                                |
|                                  | 6.86 V                               |                                |
|                                  | 5.98 V                               |                                |
|                                  | 15.7 A                               |                                |
|                                  | 17.54 A                              |                                |
|                                  | 16.61 A                              |                                |
|                                  | 104.93 W                             |                                |
|                                  | 120.7 W                              |                                |
|                                  | 99.74 W                              |                                |
3.3 Discussion
From the results given in figure 4, 5 and table 3, it can be concluded that the solar modules with mirror reflector or MR has a higher output power of 15% (120.7 W to 104.93 W) and 21% (120.7 W to 99.74 W) compared to NR and AR respectively. Even though NR has a better result in voltage than the other two conditions, MR has drawn more current. This current compensation has produced more power for solar modules with MR scheme. Theoretically, this result is correct and corresponds to the previous research that utilizes the reflectors/concentrators in improving the output power of solar cells [9] [10] [11] [12] [13].

However, the result of AR is expected to be higher than NR. From the measurement results, the AR mean value of voltage and power are 20% (5.98 V to 7.47 V) and 5% (99.74 W to 104.93 W) lower than NR. Only the current that produced 5.9% (16.61 A to 15.7 A) more than NR. This can be caused by improper installation of the aluminum reflector. In figure 4, the aluminum reflector is not smoothly stuck to the frame. Thus, the sunlight is not accurately reflected on the solar cells. Additionally, solar radiation retrieved from NASA comes from satellite and is considered less accurate than ground-based observational method [14]. Otherwise, conducting measurements for all three conditions on the same day would give more appropriate result on the output.

4. Conclusion
Based on the analysis of the influence of reflector used on solar power plan system in Batik Tugiran, then conclusions can be drawn as follows: Firstly, the overall result of the solar panel with MR condition could increase the mean output power up to 15% or 15.77 Watt compared to the one without reflector (NR). Secondly, the research method could be enhanced to improve the reflector’s effect on the solar module system. Some improvements on the methodology that can be implemented are measuring the NR, MR, and AR at the same day to ensure the similarity of radiation absorbed by the solar cells, proper installation on the aluminum reflector, and collecting more measurement data for higher justification on the final results.

5. Acknowledgments
The authors would like to thank Universitas Muhammadiyah Yogyakarta and Batik Tugiran Home Industry for supporting the research and writing of this paper.

References
[1] World Energy. World Energy Resources: Solar. In: World Energy Council 2013. 2013. p. 2. Available from: https://www.worldenergy.org/wp-content/uploads/2013/10/WER_2013_8_Solar_revised.pdf
[2] Dirjen Energi Baru Terbarukan dan Konservasi Energi. Statistik EBTKE 2016. 2016. 16 p. Available from: http://ebtke.esdm.go.id/post/2017/03/07/1583/statistik.ebtke.2016
[3] Suhartanto T. Tenaga Hibrid (Angin dan Surya) di Pantai Baru Pandansimo Bantul Yogyakarta. J Nas Tek Elektro dan Teknol Inf. 2014;3(1):76–82. Available from: http://ejnteti.jteti.ugm.ac.id/index.php/JNTEI/article/view/48/68
[4] Pae MG, Prasetyo T, Suharyanto S, Haryono T, Prasetyo RB. Effect of Load Growth on PLTH Baron Techno Park Performance. IJITEE (International J Inf Technol Electr Eng). 2018 Apr 24;1(4):125–31. Available from: https://jurnal.ugm.ac.id/ijitee/article/view/35028
[5] Balai Besar Teknologi Konversi Energi. Sistem PLTH (EBT). [cited 2019 Aug 14]. Available from: http://btp.b2tke.bppt.go.id/fasilitas/sistem-pembangkit-listrik-hibrida/

[6] Syahputra R, Soesanti I. Application of green energy for batik production process. J Theor Appl Inf Technol. 2016;91(2):249–56. Available from: http://www.jatit.org/volumes/Vol91No2/4Vol91No2.pdf

[7] United Nations Educational, Scientific and CO. Indonesian Batik. [cited 2019 Aug 14]. Available from: https://ich.unesco.org/en/RL/indonesian-batik-00170

[8] Muchammad, Efliyana BH. Pengaruh Suhu Permukaan Photovoltaic Module 50 Watt Peak Terhadap Daya Keluaran Yang Dihasilkan Menggunakan Reflektor. Univ Diponegoro. 2011

[9] Karnadi K. Peningkatan Daya Output Panel Surya Dengan Penambahan Reflektor Cermin Datar Dan Allumunium Foil. J Tek Elektro Univ Tanjungpura. 2017;1(1):1–3. Available from: http://jurnal.untan.ac.id/index.php/jteuntan

[10] Negara IBKS, Wijaya IWA, Pemayun AAGM. ANALISIS PERBANDINGAN OUTPUT DAYA LISTRIK PANEL SURYA SISTEM TRACKING DENGAN SOLAR REFLECTOR. 2016;3(1).

[11] Sidopekso S, Febtiwiyanti AE. Studi Peningkatan Output Modul Surya Dengan Menggunakan Reflektor. J Fis Teor EKskperimen, dan Fis Apl. 2010;12(3):101–4. Available from: https://ejournal.undip.ac.id/index.php/berkala_fisika/article/view/2767/pdf

[12] Rizk J, Hellany A, Nagrial M. Reflectors and Concentrators for Solar Panels. Recent Res Environ Energy Plan Pollut. Available from: https://pdfs.semanticscholar.org/39ad/70a115836cffb18489163e3128aeb1218153.pdf

[13] H.AL-Hamadany A, Al-Abideen FSZ, Ali JH. Effect of Angle Orientation of Flat Mirror Concentrator on Solar Panel System Output. In: IOSR Journal of Computer Engineering [Internet]. 2016. p. 16–23. Available from: http://www.iosrjournals.org/iosr-jce/papers/Vol18-issue1/Version-1/C018111623.pdf

[14] Jr PWS, Westberg D, Chandler WS, Zhang T, Hoell JM. Prediction Of Worldwide Energy Resource (POWER). 2017 [cited 2019 Aug 14]. Available from: https://power.larc.nasa.gov/documents/AgroclimatologyMethodology.pdf