Comparison of predictive performance and measurement of off-grid 15 kWp solar power generation in Aceh Tamiang

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Abstract. In 2015, the Government, through a special allocation fund, has finished constructing an off-grid 15 KWp off-grid solar power plant in Paya Tampah Village, Aceh Tamiang district. The long-term reliability of solar power plants is highly reliant on on-site measurements because of the vagueness in some of the constantly-changing variables such as irradiation, drought rate, which possibly lead to cause significant power losses and which turn out to also affect the estimated cost of PV (kWh). With the aim of upgrading capabilities in off-grid solar power plant planning especially in the province of Aceh, this paper outlining detailed comparison of the results of calculating the performance of off-grid 15 KWp off-grid solar power among system performance measurement results after 2 years of operation. Performance calculations performed with the assistant of PVsyst software. The measurement results characterize the total power generated by the off-grid solar power plant is 15 kWp and used by 38 households. The result of this investigation is expected to be used by local governments to be a benchmark on the future planned off-grid solar power plant planning.

1. Introduction
Aceh Tamiang Regency is one of the districts in Aceh Province, neighboring to the eastern part of North Sumatra Province and discovered at coordinates 03053’-04032’ North Latitude and 97043’-98014’ East Longitude, with an area of 1,957.25 km².

Aceh Tamiang Regency acquired the status of an authoritative Regency under Law Number 4 of 2002 concerning the establishment of Aceh Tamiang District in Aceh Province. In general, newly established districts ordinarily need much improvement, i.e., human resources, government, infrastructures, and other sectors. Infrastructure is a demanding sector urgently to addressed mainly in the effort to provide sufficient electricity, especially for the people of Aceh Tamiang.

The district government of Aceh Tamiang has made various efforts in answering the community's demand for electricity. These efforts resemble more evident outcome after the implementation of the electricity network development program into the village. With the existence of electricity, people in this area can enjoy the facilities that they cause, such as the ease of using electronic equipment that requires electricity as a source of energy.

In 2017, around 98.70 percent of households in Aceh Tamiang Regency had used electricity from state electric company, Perusahaan Listrik Negara (PLN), as their primary electrical source, while the
remaining 0.77 percent used off-grid electricity. Utilization of new renewable energy sources is an alternative resource to suffice the electricity requirements by the community not covered by PLN. In this concern, in 2015, the local government built 15 MW of solar power plants to satisfy the electricity demands at transmigration housing locations located in Paya Tampah village.

This study is intended to gauge the performance of the Solar Power Plant (PV off-grid) in Paya Tampah village after operating for approximately two years by comparing the electricity output according to the design with the measurement results. There have been many Off-grid PV design methods proposed by researchers, i.e., Bouzguenda et al. [1], who has designed 2 kW off-grid solar PV system. The design, simulation, and analysis were carried out using PVsyst V6.12 software package. Amani has conducted a Feasibility Analysis for A Stand-Alone Photovoltaic System in Ouagadougou (Burkina Faso) [2]. The analysis was carried out with the PVsyst V6.12 software package.

Ishaq et al. conducted a Design of An Off Grid-Photovoltaic System: A Case Study of Government Technical College, Wudil, Kano State [3]. Many other researchers have proposed methods for designing PV off-grid [4–6].

While the comparison method of field measurement results with the results of the design has been carried out, among others, by Saber et al., who conduct of PV (photovoltaics ) performance evaluation and simulation-based energy yield prediction for tropical buildings [7], Boughamrane compared the results of the simulation with the results of measurements on the PV grid [8]. Palmero compared the results of software simulations with the results of measurements on the PV grid [9].

Rehman proposed the PV off-grid evaluation method [10], Querikiol proposed evaluating the performance of PV off-grid using Homer software [11]. Many proposals about methods for evaluating off-grid PV and PV grids [12-14]. In this study, a study of the comparison of Predictive Performance and Measurement of Off-Grid studies of 15 kWp Solar Power Generation in Aceh Tamiang has conducted.

2. Material and methods
This study begins with measuring the performance of the PV off-grid Paya Tampah, which is approximately 15 km from the center of the city of Aceh Tamiang. Figure 1 shows the condition of PV-off-grid Paya Tampah.

Figure 1. PV-Off-grid of Paya Tampah village, Aceh Tamiang district.
Performance measurements were carried out through direct observation of the control instruments attached to the Paya Tampah PV off-grid. The next activity was to design a 15 kWp PV-off-grid using PVsyst software. Table 1 Description of electricity consumption by residents of Paya Tampah village. Table 2 lists all types of PV modules and inverters inputted on PVsyst, which also similar to the type installed in PV-off-grid Paya Tampah.

### Table 1. Electricity consumption by residents of Paya Tampah village.

| Number | Power | Use | Energy |
|--------|-------|-----|--------|
| Lamps (LED or fluo) | 38 | 25 W/lamp | 12 h/day | 11400 Wh/day |
| TV/PC/Mobile | 2 | 75 W/app | 12.5 h/day | 1875 Wh/day |
| Public facility | 1 | 35 W/app | 14 h/day | 490 Wh/day |
| Powerhouse | 3 | 10 W tot | 24 h/day | 720 Wh/day |
| Street lamp | 5 | 10 W tot | 13 h/day | 650 Wh/day |
| Stand-by consumers | 1 | 10 Wtot | 24 h/day | 240 Wh/day |
| Total daily energy | | | | 15375 Wh/day |

### Table 2. PV modules and batteries used in the simulation.

| Geographical Site | Paya Tampah |
|-------------------|-------------|
| Situation | |
| Latitude | 4.37° N |
| Longitude | 98.03° E |
| Time zone | UT+7 |
| Altitude | 15 m |
| PV module | |
| Model | Si-Mono 200Wp 96 cells |
| Number of PV modules | 42 |
| In series | 2 modules |
| In parallel | 21 strings |
| Array operating characteristics (50°C) | |
| U mpp. | 79 V |
| I mpp | 94 A |
| Battery | |
| Model | OPzS Solar 1020 |
| Voltage | 26 V |
| Nominal Capacity | 2453 Ah |
| Nb. of units | 8 in series x 11 in parallel |
| Controller | |
| Model | Universal controller with MPPT converter |
| Technology | MPPT converter |
| Temp coeff. | -5.0 mV/°C/elem. |
| Converter Maxi efficiencies | 97.0 % |

### 3. Result and discussion

The simulation results apprise regarding potentially available energy approximately 9632 kWh/year, used energy 8066 kWh/year, excess (unused) 188 kWh/year, performance ratio 64.34 %, missing energy 440 kWh/year. Figure 2 and Table 3 represent complete simulation results.

Figure 2 reveals that the supplied to user energy reaches 2.63 kWh/kWp/day when compared with the results of observations in the field where residents can only take advantage of the availability of electricity for 2-4 hours per day. The simulation exhibit required consideration for the detail conditions of solar radiation and environmental temperature of installed PV-off-grid.
Table 3 presents the energy need of the user (Load), and energy supplied to the user. The table describes the planned PV-off grid able to provide all the electrical energy demanded for every month throughout the year. This observation provides a different result against field result during the rainy season 5-6 days the community can only enjoy electricity for 2 hours, at night.

**Table 3. Energy distribution based on simulation results.**

|       | GlobHor kWh/m² | GlobEff kWh/m² | E Avail kWh | E Unused kWh | E Miss kWh | E User kWh | E Load kWh | SolFrac |
|-------|----------------|----------------|-------------|--------------|------------|------------|------------|---------|
| January | 128.2          | 135.1          | 896.5       | 42.31        | 0          | 722.4      | 722.4      | 1       |
| February | 123.3          | 123            | 812.6       | 44.22        | 34         | 618.5      | 652.5      | 0.948   |
| March  | 157.2          | 144.1          | 952.8       | 83.94        | 0          | 722.4      | 722.4      | 1       |
| April   | 144            | 118.4          | 795.2       | 0            | 0          | 699.1      | 699.1      | 1       |
| May     | 143.3          | 109.9          | 748.4       | 0.04         | 16         | 706.4      | 722.4      | 0.978   |
| June    | 134.8          | 97.4           | 664.9       | 0.21         | 141.8      | 557.3      | 699.1      | 0.797   |
| July    | 144            | 106            | 723.6       | 0.08         | 112.5      | 609.9      | 722.4      | 0.844   |
| August  | 139.3          | 112.1          | 763.5       | 0.04         | 83.6       | 638.9      | 722.4      | 0.884   |
| September | 131.7         | 115.8          | 779         | 0            | 32.3       | 666.8      | 699.1      | 0.954   |
| October | 137.8          | 134.9          | 887.5       | 0.09         | 20         | 702.5      | 722.4      | 0.972   |
| November | 118.6         | 123.7          | 821.7       | 17.19        | 0          | 699.1      | 699.1      | 1       |
| December | 111.4          | 117            | 786         | 0.08         | 0          | 722.4      | 722.4      | 1       |
| Year    | 1613.6         | 1437.5         | 9631.6      | 188.2        | 440.2      | 8065.8     | 8506       | 0.948   |

Legends:  
- **GlobHor**: Horizontal global irradiation  
- **GlobEff**: Effective Global, corr. for shadings  
- **E Avail**: Available Solar Energy  
- **E Unused**: Unused energy (full battery) loss  
- **E Miss**: Missing energy  
- **E User**: The energy supplied to the user  
- **E Load**: The energy need of the user (Load)  
- **SolFrac**: Solar fraction (EUsed / ELoad)
4. Conclusion
From the measurement results of PV-off-grid performance installed in Paya Tampah Village, the resulting voltage is 219-220 Volt, and the output current is in the range 2-3 A. The maximum duration for electricity consumption by the community ranges between 2-4 hours. Estimates of average electricity consumption are about 10 hours. By comparing the results of the prediction to the results of measurements, it is evident that pre-feasibility studies should articulate a more detailed measurement of actual solar radiation. Proper interpretation of result disparities in the prediction with measurement results is crucial, and therefore, decent selection and data input of the PV module and inverter is a necessity.

References
[1] M Bouzguenda, A A Omair, A Al Naem, M Al-Muthaffar and O B Wazir 2014 Design of an off-grid 2 kW solar PV system. 2014 9th International Conference on Ecological Vehicles and Renewable Energies, EVER 2014 1–6.
[2] K L Amani 2016 Feasibility Analysis For A Stand-Alone Photovoltaic System In Ouagadougou (Burkina Faso): Techno-Economical Approaches. International Journal of Pure and Applied Physics 12(1) 9–27.
[3] M Ishaq and U H Ibrahim 2013 Design Of An Off Grid-Photovoltaic System: A Case Study Of Government Technical College, Wudil, Kano State. International Journal of Scientific & Technology Research. 2(12).
[4] J Uwibambe 2017 Design of Photovoltaic System for Rural Electrification in Rwanda. The University of Agder.
[5] S Y Wong 2013 An Off-Grid Solar System for Rural Village Implementation in East Malaysia. IEEE 1–96.
[6] A Rajeev and K S Sundar 2013 Design of an off-grid PV system for the rural community. Proceedings - 2013 International Conference on Emerging Trends in Communication, Control, Signal Processing, and Computing Applications, IEEE-C2SPCA.
[7] E M Saber, S Eang, S Manthapuri, W Yi and C Deb 2014 PV (photovoltaics) performance evaluation and simulation-based energy yield prediction for tropical buildings. Energy.1–8.
[8] L Boughamrane, M Boulaid, A Tihane, A Sdaq, K Bouabid and A Ihlal 2016 Comparative analysis of the measured and simulated performance of the Moroccan first MV grid-connected photovoltaic power plant of Assa, Southern Morocco. Journal of Materials and Environmental Science. 7(11) 4064–72.
[9] A Palmero-Marrero, J C Matos and A C Oliveira 2015 Comparison of software prediction and measured performance of a grid-connected photovoltaic power plant Journal of Renewable and Sustainable Energy 7(6).
[10] S Rehman and I El-Amin 2012 Performance evaluation of an off-grid photovoltaic system in Saudi Arabia. Energy. 46(1) 451–8.
[11] E M Querikiol and E B Taboada 2018 Performance Evaluation of a Micro Off-Grid Solar Energy Generator for Islandic Agricultural Farm Operations Using HOMER. Journal of Renewable Energy 2018 1–9.
[12] N A A John 2015 Performance Evaluation of On-Grid and Off-Grid Solar Photovoltaic Systems. IJireeice. (2) 20–3.
[13] R Sharma and S Goel 2017 Performance analysis of an 11.2 kWp rooftop grid-connected PV system in Eastern India. Energy Reports 3 76–84.
[14] J H Jo, K Ilves, T Barth and E Leszczyński 2017 Correction: Implementation of a large-scale solar photovoltaic system at a higher education institution in Illinois, USA. AIMS Energy. 5(2) 313–5.