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Profitability assessment of PV rooftop implementation for prosumer under net metering scheme in Indonesia

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Andri Y. Rosyad[1] ✉, *Candra A.D. Wahyudi*[1], *Catherine J. Noakes*[2]

[1]*PT PLN (Persero), Jakarta, Indonesia*
[2]*University of Leeds, Leeds LS2 9JT, UK*
✉ *E-mail: andri.yanuar@pln.co.id*

Abstract: This study conducts an analysis of photovoltaic (PV) rooftop potential for domestic application in Indonesia. In this study, the potential solar energy is simulated by using IES VE software coupled with a Monte Carlo probabilistic approach to account for the variability of solar energy. Economic analysis is undertaken based on the calculated solar energy using an exceedance probability of 90%. The economic analysis is developed under the latest net metering scheme as regulated by Regulation of Minister of Energy and Mineral Resources in Indonesia. The study shows that despite a mismatch between the peak solar generation and the peak demand for power that rooftop PV is still cost effective. Using the latest net metering scheme, the costumer is benefiting from a PV rooftop investment despite the significant reduction of export energy price compared to the previous net metering regulation.

1 Introduction

The sharp increase in fossil fuel energy price has forced energy practitioners to utilise renewable energy as an alternative solution to generate electricity. Despite the growth of renewable energy utilisation in generating electricity, the data from World Energy Council (2016) shows that non-renewable energy remains the primary resources of energy with 32.94, 29.2 and 23.85% out of total energy consumption for oil, coal and gas, respectively. Even though non-renewable energy still has the largest share of energy consumption, energy consumption worldwide has seen a significant increase in solar-powered electricity. The marked increase in solar-powered electricity is influenced by several factors namely: technology development, price decrease and deployment of subsidies [1]. The study from [2] shows that the installation of solar photovoltaic (PV) rooftop could contribute up to 20% of the nation's electricity if PV rooftop is installed in the residential and commercial building.

The integration of the building structure and renewable energy technology enable architect and designers to transform the existing building from energy users to energy producers [3]. However, to gain more benefits from installing PV rooftop in existing buildings, Azadian and Radzi [4] suggest incorporating some factors, namely technical improvements, supportive government laws and financial aids. The study from [5] envisages the advantages of using PV as a solution for limited space on the ground, reduced transmission and distribution losses, environmentally friendly and capacity building for local electrician.

According to the study from [6], there are growing numbers of installed capacity on grid PV compared to installed capacity of off grid PV. Moosavian *et al.* [6] discuss the data about the growing capacity of on-grid in some countries and factors affecting this trend. The growing numbers of on-grid PV is likely caused by the policy implemented by the government in the respective country to encourage renewable energy development. Particularly in Indonesia, the government has released the Decree of Minister of Energy and Mineral Resources (MEMR) No. 49 year 2018 on 15 November 2018 which regulates the net metering system scheme of PV rooftop from residential costumer. Under this regulation, the costumer is permitted to export the excess of the energy produced from PV rooftop (after self-consumption) to the grid owned by PT Perusahaan Listrik Negara (PLN)/Indonesian Electricity State-Owned Company. The export price will be multiplied by 65% of retail price. The export price of the latest regulation is reduced by 35% from the previous one. In the previous regulations, the export price of electricity is equal to the retail tariff. This research is developed to investigate the impact of the latest net metering scheme to the profitability of the costumer by combining the data from modelling software and economic feasibility modelling.

2 Methodology

2.1 Modelling of PV rooftop

According to [7], the solar energy generated from the PV panel is the result of multiplication of several factors namely: panel area (m^2), solar panel yield or efficiency (%), average solar radiation in certain period (kWh/m^2) and performance ratio.

The area A refers to the total area of solar panel. In this analysis, one module of solar cell is assumed to produce 250 Wp with the dimension of 1650×990 mm. So that, the total area for one module of solar panel is ~1.6 m^2. Furthermore, the total area of solar panel mounted on the roof is 1.6 m^2 times the number of modules.

According to [8], r is defined as the efficiency of solar panel and can be determined by electrical power (in kWp) divided by the area of one panel. In this model, r value is equal to 0.25 kWp divided by 1.6 m^2 resulting r value 15.6%. This value is based on the best practice assumption that this formula applies for the standard test condition (STC) which assumes radiation = 1.000 W/m^2, cell temperature = 25°C, wind speed = 1 m/s, AM = 1.5. Based on the information from [8], the value of performance ratio depends upon the condition of site, type of technology and the system sizing. This parameter indicates the coefficient of losses for several factors for example: inverter losses, temperature losses, DC cable losses, AC cable losses, shadings, dust and weak radiation. According to [8], the performance ratio (PR) ranges from 0.5 to 0.9, with the most common value 0.75.

According to [9], the solar resources and plant losses have the greatest uncertainty among the parameters in the calculation. Therefore to deal with the uncertainty caused by these two variables, a probabilistic approach using a Monte Carlo methodology is used. The other variables were determined to have an insignificant impact on the outcome. Solar radiation is the first random variable in this calculation model. To obtain the data of solar radiation energy per day (kWh/m^2/day), the solar flux (kW/m^2) is retrieved from Vista Pro in IES VE and analysed and plotted in excel. Solar energy per day (kWh/m^2) is obtained by accumulating the data of solar flux for one day and for the whole year. The second random variable is PR. Due to the limited data provided, a triangular distribution model is used considering the fact that there is a minimum value, most likely value and maximum value. According to [10], triangular distribution is useful when actual data distribution is not available because the data is too difficult to be obtained. The final product of the Monte Carlo model is the cumulative probability curve of solar energy (Wh/m^2), which allows the exceedance probabilities of solar energy generated by solar panel (Wh/m^2) per day on the rooftop to be established.

2.2 Economic feasibility modelling

According to [11], the calculation of economic feasibility of a PV rooftop installation under net metering scheme can be generally presented by (1).

Cash flow formula for net metering scheme:

$$\text{Net cash flow} = \sum_{y=1}^{y=n} \frac{(S_y \times P_y) + (T_y \times P_{T_y}) - \text{OM}}{(1+r)^{y-1}} \qquad (1)$$

S_y is the electricity consumed for domestic purpose (kWh); T_y is the electricity exported to grid in year y (kWh); P_y is the retail price of electricity in year y (IDR/kWh); P_{TY} is the electricity export price to the grid/65% retail price (IDR/kWh); n is the lifetime (years); $\text{NPV} = \text{Net cash flow} - I_0 - \left(I_R/(1+r)^m\right)$; I_R is the cost for replacement (IDR); m is the lifetime of inverter (IDR); OM is the operations and maintenance cost; r is the discount rate.

The assumptions for the economic feasibility modelling are presented in Table 1. This data is obtained from a questionnaire delivered to several PV manufacturers and contractors, supplemented by interviews with the founder and chairman of the PV rooftop association in Indonesia.

3 Results

3.1 Solar energy generation

The analysis assumes a simple house model with a roof area of 36 m^2 (house type 36). This model is typical of housing in urban areas of Indonesia where the space is very limited. The surface drawing of roof is made to illustrate the area of which the solar radiation is absorbed by PV rooftop.

The result of the probability (P90) calculation for each direction for PV rooftop installed in house type 36 is presented in Table 2. All of the calculations in this paper use P90 (solar energy/day with confidence level of 90%).

Table 1 Assumptions of associated parameters

No.	Variables	Assumptions
1	lifetime of PV rooftop	25 years
2	discounted rate (i)	8%
3	inverter replacement	every 10 years
4	annual electricity price increase	10%
5	annual production degradation	0.64%
6	annual maintenance cost	1% of total system cost (subject to 5% annual increase)
7	initial investment (including installation)	IDR 12.000.000/kWp
8	inverter cost	25% of total initial investment

IDR refers to Indonesian Rupiah

Table 2 P_{90} of energy generated from PV rooftop

No.	Scenario	P_{90}, Wh/day
1	east-facing house type 36	5246.46
2	west-facing house type 36	5074.06
3	north-facing house type 36	4996.09
4	south-facing house type 36	4921.12

3.2 Coincidence peak demand

According to [12], the economic value of solar PV relies on the chronological coincidence between generation and load, because PV solar is intermittent technology which produces energy regardless it is required or not. According to Fig. 1, it can be seen that in each direction, there is timing mismatch between the household electricity demand and PV rooftop solar energy. In Indonesia, typically the solar energy yields a maximum value in the middle of the day, in the same time when the household electricity demand is low.

3.3 Profitability assessment

From Table 3, it can be seen that the west-facing direction is the most profitable compared to any other direction, because the self-consumption of west-facing direction is more than any other directions; therefore west-facing generates more saving on electricity bills.

3.4 Sensitivity analysis

In Fig. 2, a sensitivity analysis is developed by adding and subtracting ±20% of the current value of respective variables. The red bar

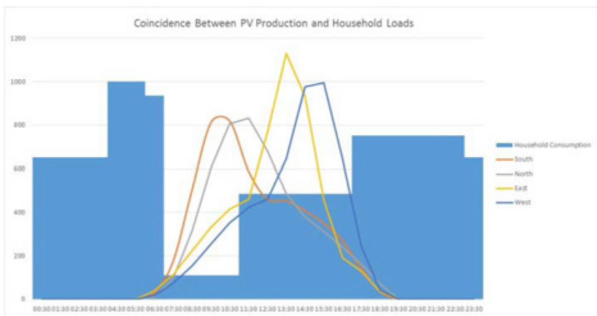

Fig. 1 *Timing mismatch between PV rooftop and household electricity demand*

Table 3 Profitability of PV rooftop from different directions

Roof orientation	Payback, years	NPV, IDR	IRR, %	LCOE, IDR/kWh
north	12	15.044.571	11.52	1403.848
south	12	13.912.229	11.28	1425.234
east	12	18.226.592	12.17	1336.854
west	12	20.214.519	12.46	1359.685

IDR refers to Indonesian Rupiah

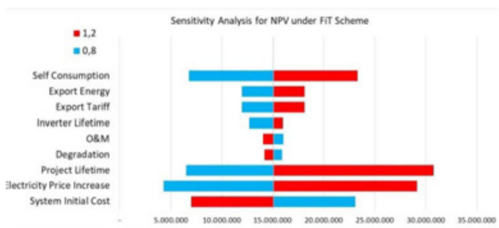

Fig. 2 *Sensitivity analysis*

indicates the condition when the current value is added by 20% of the current value, in contrast blue bar indicates the subtraction of 20% of the current value. From Fig. 2, there are four variables which are considered to be the most influential among other variables. These variables are: solar energy, project lifetime, electricity price increase and system initial cost, whereas the other variables are not considered influential to the total outcome of NPV.

4 Conclusion

(i) There is a problem related to timing mismatch between coincidence peak demand and solar energy generation from PV rooftop. This non-coincidence event causes the lack of self-consumed electricity energy from PV rooftop to feed the household electricity demand.
(ii) According to the economic scenario analysis of PV rooftop, from the view of the investor, it can be concluded that investment of PV rooftop under the latest net metering system scheme is profitable. This is due to the rapid decrease of PV rooftop investment cost in the recent years.
(iii) Despite the timing mismatch, according to the modelling calculations, the self-consumption electricity energy is more than the export energy. Therefore, the reduced export energy price by 35% of retail price as regulated by the latest net metering scheme has no significant impact on the profitability of the costumer. The profitability of PV rooftop relies on the roof direction which produces most self-consumed electricity energy. Therefore, the time when PV rooftop can fulfil the peak demand of the household electricity consumption is of paramount importance.
(iv) After examining the scenario analysis for PV rooftop economic aspect, it can be found that the levelised cost of electricity (LCOE) is not competitive compared to the other generating technologies. In the future, it is possible that the PV rooftop could be more cost competitive considering the gradual decrease of PV cell price in the global market.
(v) According to the sensitivity analysis, maximising the benefit of PV rooftop can be undertaken by using two approaches:

- Technology with the higher efficiency and longer lifetime is required to provide a reliable solar energy production. However, the trade-off between efficiency, lifetime and price should be taken into consideration carefully.
- Increasing the use of self-consumed electricity can generate more profit for electricity costumer. This research proves that the roof direction is more profitable when producing more coincidence peak demand between electricity generated from PV rooftop and household peak demand. The self-consumed can also be maximised by installing battery storage in order to solve the problem timing mismatch. Therefore, further study regarding the battery application for on-grid PV is required.

5 References

1 Hirth, L.: 'The market value of variable renewables the effect of solar wind power variability on their relative price', *Energy Econ.*, 2013, **38**, pp. 218–236
2 Spiegel, R. J., Greenberg, D. L., Kern, E. C., *et al.*: 'Emissions reduction data for grid-connected photovoltaic power systems', *Sol. Energy*, 2000, **68**, pp. 475–485
3 Abdallah, T., Diabat, A., Rigter, J.: 'Investigating the option of installing small scale PVs on facility rooftops in a green supply chain', *Int. J. Prod. Econ.*, 2013, **146**, pp. 465–477
4 Azadian, F., Radzi, M. A. M.: 'A general approach toward building integrated photovoltaic systems and its implementation barriers: A review', *Renew. Sustain. Energy Rev.*, 2013, **22**, pp. 527–538
5 Ghosh, S., Nair, A., Krishnan, S. S.: 'Techno-economic review of rooftop photovoltaic systems: case studies of industrial, residential and off-grid rooftops in Bangalore, Karnataka', *Renew. Sustain. Energy Rev.*, 2015, **42**, pp. 1132–1142
6 Moosavian, S. M., Rahim, N. A., Selvaraj, J., *et al.*: 'Energy policy to promote photovoltaic generation', *Renew. Sustain. Energy Rev.*, 2013, **25**, pp. 44–58
7 Schoenmaker: 'Developing a smart grid simulation model from an end-users perspective'. Master's, University of Groningen, 2014
8 Photovoltaic Software: 'How to calculate the annual solar energy output of a photovoltaic system? [online]', 2015. Available at http://photovoltaic-software.com/PV-solar-energy-calculation.php, accessed 29 August 2017
9 Williams, C.: 'Modeling solar production risk 101 – an introduction to P50 and P90 production levels [online]' (Heatspring Magazine, USA, 2014). Available at https://blog.heatspring.com/modeling-solar-production-risk-101-an-introduction-to-p50-and-and-p90/, accessed 19 August 2017
10 Glickman, T. S., Xu, F.: 'The distribution of the product of two triangular random variables', *Stat. Probab. Lett.*, 2008, **78**, pp. 2821–2826
11 Johansson, N., Karlsson, J.: 'Economic feasibility for solar PV in Swedish office buildings'. Master's Thesis, Chalmers University of Technology, 2015
12 Lamont, A. D.: 'Assessing the long-term system value of intermittent electric generation technologies', *Energy Econ.*, 2008, **30**, pp. 1208–1231