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A Simplified Method: System Size and Cost Estimation of Grid Connected Photovoltaic (GCPV) System

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Abstract: There are various types of Renewable Energy (RE) that has been studied by many researchers in order to find a cost-effective energy generation in reducing the non-renewable energy source. In this study, the solar energy was suggested in order to apply the Net Energy Metering (NEM) scheme that has been introduced effective on 1st January 2019, by Malaysian government in achieving 20% national RE target in electricity power mix, reducing the dependency on imported fossil fuels. Based on the data and results, the suitable size of solar panel for a house can be determined based on the daily electricity usage. The findings show that the system size and the cost itself also depends on the estimated amount solar generated set by the consumer.

Keywords: Grid Connected, Net Energy Metering, Photovoltaic and Renewable energy

I. INTRODUCTION

Nowadays, electricity consumption for a household is increasing throughout the year. Renewable energy system for residential is a system which consumer can generate electricity at their house. There are many forms of renewable energy for example, solar, wind power, hydroelectric, biomass, geothermal and other forms of energy [1,2,3]. By using a renewable energy, it can help to achieve national RE target in reducing the dependency on imported fossil fuels [4]. One of a common type of renewable energy used for residential is solar photovoltaic (PV) system. The common type of solar system used for residential is Grid Connected Photovoltaic (GCPV) system. It is designed to operate in parallel and interconnected with the electric utility grid. The primary component in GCPV system is the inverter.

The inverter converts the Direct Current (DC) power produced by the PV array into Alternating Current (AC) power consistent with the voltage and power quality requirements of the utility grid and automatically stops supplying power to the grid when the utility grid is not energized. When the electrical loads are greater than the PV system output, the balance of power required by the loads is received from the electric utility.The utility meter will measure the electricity draw or exported to the grid [5]. The grid will provide electricity demand by the load when the system fails or no power generated by PV array [6,7]. At night, electricity will be fully supplied by the conventional grid. The schematic diagram of Grid GCPV system is shown in Figure 1.

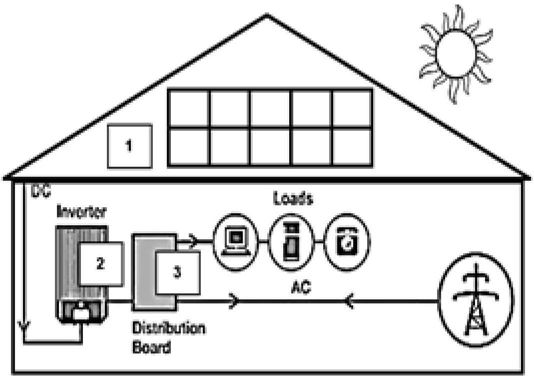

Fig. 1 Grid Connected Photovoltaic (GCPV) system

Net Energy Metering (NEM) is a concept where the energy produced installed by the solar PV system are being consumed first and the remaining excess will be exported to TNB on a one to one offset basis while Malaysia's Feed in Tariff (FiT) is a system that obliges Distribution Licensees (DLs) to buy from Feed-in Approval Holders (FIAHs) the electricity produced from renewable resources and sets the FiT rate [8]. The significant difference between NEM and FiT is that NEM uses the energy and export the energy back to the grid [9] while FiT by the obligation of DLs will pay for renewable energy supplied to the electricity grid for a specific duration and rate [10]. The NEM scheme also improved the FiT scheme by improving the return of investment of solar PV.

II. METHODOLOGY

The amount of electricity a solar panel can produce depends on three main reasons which is the size of the solar panel, the efficiency of the solar cells inside and the amount of sunlight the panel received.

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The data regarding the electricity bill and usage is collected to estimate the size of solar panel. Meanwhile, the data regarding the weather, rainfall, humidity and cloudy is required to see the meteorology pattern in Selangor, Malayia.

Table. 1 Average temperature in Selangor from 2018 to 2019

Month	Temperature (°C)
January 2018	24, 26, 29
February 2018	25, 27, 31
March 2018	25, 28, 31
April 2018	26, 28, 31
May 2018	26, 28, 31
June 2018	26, 28, 31
July 2018	26, 28, 31
August 2018	26, 28, 32
September 2018	26, 28, 31
October 2018	26, 29, 31
November 2018	26, 29, 31
December 2018	25, 29, 31
January 2019	25, 29, 32
February 2019	25, 30, 33
March 2019	26, 30, 33

Data collection

Data about the weather in Selangor is collected to estimate the amount of sunlight. Table 1 shows the average temperature whereas; Table 2 shows the average of rainfall and cloudy from January 2018 to March 2019 [11].

Table. 2 Average of rainfall, humidity and cloudy from 2018 to 2019

Month	Rainfall (days)	Length (mm)	Cloudy (%)
Jan-Mar 2018	67	35.91mm	31.33
Apr-June 2018	74	58.17mm	34
Jul-Sept 2018	58	36.56mm	25.67
Oct-Dec 2018	87	390.78mm	56.33
Jan-Mar 2019	85	204.87mm	47.5

Based on the temperature from Table 1, the hottest weather is on March 2019 where the temperature can go up to 33°C and the most cloudy and rainy is during January 2018 with minimum temperature of 24°C. Meanwhile, based on the rainfall and cloud from Table 2, the most cloudy and rainy is in between October to December 2018 and the least cloudy and rainy is in between July to September 2018. During the hot weather, the amount of sunlight the panel is getting can take up to 3.5 to 5 hours [12].

Electricity Consumption

In this research, the suitable solar panel size is determined based on the daily electricity usage of the house. The latest usage of electricity is recorded for the latest 6 months [8] as shown in Table 3 below:

Table. 3 Average electricity usage on the selected month

Month	Electricity	
	Bill (RM)	Usage (kWh)
October 2018	569.50	1172
November 2018	492.85	1032
December 2018	509.45	1059
January 2019	458.45	976
February 2019	583.20	1179
March 2019	559.21	1140

The data of electricity bill and usage above is obtained from the focus group interview conducted in Selangor area. The group is randomly select based on the type of house and number of people living inside the house which is the double storey type of house and the people living inside the house is in between 4 to 6 people.

III. RESULTS AND DISCUSSIONS

Results

Based on the data provided in methodology, the system size and the cost of Grid connected Photovoltaic (GCPV) can be estimated. The following result shows the proposed calculation of average solar PV supply for residential in Selangor. The electricity bill and the average kWh usage per day is referred in order to get the suitable size. The system size can be determined as follow:

Total average electricity usage, ΔE in kWh/month,

$\Delta E = (1172 + 1032 + 1059 + 976 + 1179 + 1140) \div 6$

$= 1093$ kWh/month

Total average electricity usage, ΔE in kWh/day,

$\Delta E = 1093 \div 30$ days

$= 36.43$ kWh/day

Based on the Malaysia Meteorology Department data, the total hours of peak sun are equivalent to 5 hours. The system efficiency loss also needs to be considered due to DC to AC conversion, friction, heat and other ineffectiveness [13]. The amount of system loss is by multiplying 1.43 to the system size.

Therefore, the proposed system size, Ss in kW,

$Ss = 36.43\text{kWh} \div 5\text{h} \times 1.43$

$= 10.4$kW is the system size needed to produce 36.43kWh/day at 5 peak sun hours.

Besides that, the amount of electricity to offset need to be fixed. Within this, a cost to install the solar PV can be determined. The system size installed for competitive cost is by multiplying RM13,000 to the proposed system size. For 100% electricity that will be covered by solar panel, the estimated system cost is as follow:

Estimated system cost in Ringgit Malaysia (RM),
Cs = 10.4kW × RM13,000 /kW × 100%
= RM135, 200 for 100% covered by solar panel.
For 70% electricity that will be covered by solar panel and 30% will be charged by Tenaga Nasional Berhad (TNB), the estimated system cost is as follow:
Estimated system cost in in Ringgit Malaysia (RM),
Cs = 10.4kW × RM13,000 /kW × 70%
= RM94, 640 for 70% covered by solar panel and 30% will be charged by TNB.

The solar PV installed will continue to produce power for 25 years and more [14]. Table 4 shows the TNB's tariff rate for residential categories:

Table. 4 TNB's tariff rate for residential [15]

TARIFF CATEGORY	UNIT	CURRENT RATE (1 JAN 2018)
Tariff A - Domestic Tariff		
For the first 200 kWh (1 - 200 kWh) per month	sen/kWh	21.80
For the next 100 kWh (201 - 300 kWh) per month	sen/kWh	33.40
For the next 300 kWh (301 - 600 kWh) per month	sen/kWh	51.60
For the next 300 kWh (601 - 900 kWh) per month	sen/kWh	54.60
For the next kWh (901 kWh onwards) per month	sen/kWh	57.10

Based on the TNB's tariff rate, the estimated charge for 30% electricity supplied by TNB, Rtnb is,
Rtnb = 1093kWh × 30% × 51.60 sen/kWh × 12 months × 25 years
= RM50, 758.92

To compare both system with the conventional one, the estimated cost of electricity that is fully supplied by TNB, Rtnb based on the TNB's tariff rate is,
Rtnb = 1093kWh × 57.10 sen/kWh × 12 months × 25 years
= RM187, 230.90

Table 5 below shows the comparison of the system size cost based on the calculation above:

Table. 5 Comparison between two type of solar PV based on cost

System type	Estimated cost of solar panel	Estimated charged by TNB (in 25 years)
System fully (100%) covered by solar PV	RM135, 200	-
System 70% covered by solar PV, 30% by TNB	RM 94, 640	RM 50, 758.92
Conventional (fully supplied by TNB)	-	RM187, 230.90

IV. DISCUSSION

Electricity that is overly produced will not be stored by the system for a grid connected type. When solar panel is overproduced, this energy will be transferred to TNB grid and distributed elsewhere. TNB meter will credit our account for producing energy for them and offset our monthly utility bill under the net metering concept which helps lowering the electricity bill. If electricity demand is higher than solar system can provide, the electricity will come from the grid [16].

The efficiency of solar panel is depending on the usage. The efficiency can be reduced by the life span of solar panel itself, the type of material the solar cell is made of and maintenance for the system due to dust, wiring, irradiance and temperature. The amount of sunlight received by solar panel can up to 5 hours average or less, if pollution is high on certain area. The amount of sunlight received also depends on the daily weather if it is too hot, rainy or cloudy. There's an average of 2 months cloudy or rainy days per year in Malaysia. During this month, solar power is not effective. For a maximum performance, the solar panel needs to be cleaned every few months as dusk accumulation reduces system's efficiency. This reduces the amount of cost needed to provide for maintenance charges.

This study is helpful in creating awareness to the consumer with the information of renewable energy which one of it is by installing solar panel at home to reduce the usage of non-renewable energy in order to save the earth.

V. CONCLUSIONS

The objective of this paper is to propose a suitable size of solar PV in two condition, which is to go for fully solar (100%) or 70% solar with 30% supplied from the grid. Based on the result, the estimated cost for a system that is 100% covered by solar PV is RM135,200. Meanwhile, the estimated cost for a system that is 70% covered by solar PV is RM94, 640 and another 30% will be supplied by TNB which will cost about RM50, 758.92 in 25 years time. The cost for both systems may differ which, a higher cost will be charged for a solar system that operates 100% in supplying electricity compared to solar system that operates 70% or lesser in supplying the electricity. But, for a long term usage, by installing a solar PV system that can fully generate electricity is more cost effective, since it can save about RM10,198.92 compared to the solar system that operates only 70% and it can save up to RM52,030.90 compared to the conventional system.
By implementing solar PV that is suitable with NEM scheme, if the system produce more that it consumes, every 1kWh exported to the grid will be offset against 1kWh consumed from the grid.

The energy produced from the installed solar PV system will be consumed first, and any excess will be exported to TNB on a one-on-one offset basis [17] which it is a return of investment by the solar PV.

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