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Feasibility Study of Grid-Connected Solar Photovoltaic (PV) System for Primary School in Johor

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ABSTRACT

This project aims to determine the potential of grid connected solar Photovoltaic (PV) implementation and project planning of solar PV System in school. Generally, the educational institution used huge amount of electricity to operate so their monthly bills is expensive. Therefore, the project planning is necessary to determine the potential of solar PV system implementation. The project planning consists of the current electricity consumed by the school and the amount of 120W Monocrystalline PV module needed by them. The cost of project are determines to identify the initial cost of this project implementation. Lastly, analysis on the profit collected by SK Pintas Raya after 20 years of solar PV system implementation proved the importance of this project.

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1. INTRODUCTION

The world is dealing with the high demand of electricity consumption due to the increasing of the number of population around the world. It leads to the high usage of natural resources to generate electricity such as fossil fuel and gas. But, the resources are almost deplete as they are non-renewable and takes thousands of years to be generated back. Due to the limited amount of non-renewable resources, the electricity cost for every country is keep on increasing.

Therefore, many studies and researches have been carried out by the academicians and one of them is the proposed of the green technology. It consists of many kinds of resources and one of them is the solar power generation. Solar power that generated from Photovoltaic (PV) module had been widely used in the world due to its ubiquity, abundance and sustainability of solar radiant energy [1].

Commonly, the Photovoltaic (PV) Module can be installed as a grid connected or stand alone PV. The main difference of both installation is their method of storage as the electricity will transmit to the grid for grid connection while battery bank is used as storage for stand alone PV. Next, PV also being installed on the rooftops or free space on land also known as solar harvesting. For solar harvesting, it need a larger space to generate bigger power for the user. For rooftop installation, smaller space is needed and the output power generated enough for the building.

In Malaysia, the final electricity consumption is 11,175 ktoe in 2015 which is equal to 129.9TWh and it is increase annually [2]. So, due to the increasing demand of electricity in Malaysia, PV system is being used under Feed in Tariff (FiT) and Net Energy Metering 2016 (NEM 2016) schemes that covers industrial, commercial and residential sectors. Next, the typical types of PV used in Malaysia consist of Polycrystalline, Monocrystalline and Thin Film Photovoltaic [3].

Nowadays, PV systems have been developed in most of the new residential areas. But, in commercial areas such as academic institutions, it is not familiar to use PV systems eventhough Malaysia has a true potential to implement the PV system. As we know, Malaysia is located in a tropical climate zone, so it has abundant amount of solar irradiance and good temperature to implement solar system. Therefore, the purpose of this research are to analyze the potential of grid connected PV system implementation in school through project planning and also to make a profit analysis on this project.

2. RESEARCH METHOD

This section will be focusing on the methods to do the project planning of the solar PV system in school. Other than that, the data collection will be discuss thoroughly in this section. The data collection is divided into meteorological data, the PV data and also the school data for this project.

2.1. Previous Research

This section will be focusing on the previous research used to do this project. First paper discussed about standard test condition (1000W/m^2,25℃) and also the set condition (800W/m^2, 25℃). It is also tested on two types of PV modules which are KD325GX (330W) and KD330GX (330W) [4]. Paper [5] discussed on the standard test condition but for different input which consist of Solar Irradiance, temperature and solar spectrum for 185W and 125W PV module. The research is quite details compared to the others due to some additional input compared to the others. Different kind of method used in paper [6] as it consists of PV1-D method, MatLAB Function, Shockley Diode Equation and also Newton Raphson method for MSX-60 (60W) PV module.

In paper [7], STP 255-20 type of PV module is being used with capacity of 255W of power for one module. Solarex MSX 60W PV module is being used in paper [1] and it has 60W power. During the first test, standard test condition with 1000W/m^2 and 25℃ is taken into account. But it is being varied from 200-1000 W/m^2 and temperature from 0-100℃. Other than that, PVX500 PV module is being used with capacity of 49W power [8]. The output power from the selected module is quite small and cannot be used for many appliances. Input parameter for this research is by using insolation 1000 W/m^2 and the temperature is 298 kelvins. PV1-D masked block is being used and the PV type is Solarex MSX 60. In the discussion, the MSX60 type will have a full performance with 60W output only during noon which the insolation is 1000 W/m^2 [9].

Last research paper that had been reviewed is discussed on the Modeling of PV Module by Using MatLAB Simulink [10]. In this research, they are using the MSR 245W PV that consume 245 W of power. The input parameter that consist of insolation and temperature are being used same as before. From all the previous paper, the method for modeling the PV module still the same which are varying the insolation and temperature. The results obtained from the simulation shown the maximum power, current and voltage capacity for each module to prove the performance of the PV panel.

2.2. Meteorological Data

The meteorological data that used in modeling of the solar PV module is obtained from RET Screen software database. This software is used for the free version on academic purpose to manage the energy and have variety of location [11]. There are many inputs data that can be found in the RET Screen software. In this research, the data that need to be consider are the Solar Irradiance (G) and Temperature (T). Solar irradiance and temperature data will be collected at location 1.8635° N, 103.1089° E which is in Parit Raja, Batu Pahat, Johor. From the data collected, data for May, June and July 2016 will be used in this project to know the average solar irradiance and temperatyre in the location stated earlier. The meteorological data is tabulated as in Table 1.

Table 1. Meteorological Data

Month (2016)	Solar Irradiation (kWh/m^2)	Solar Irradiance (kW/m^2)	Temperature (°c)
May	4.60	0.192	27.2
June	4.57	0.190	26.7
July	4.49	0.187	26.2

2.3. Photovoltaic Module

The PV characteristic is representing by the I-V curve (current-voltage relationship) and the P-V curve (power-voltage relationship) as shown in Figure 1. The PV will be at full performance during Standard Test Condition (STC) with solar irradiance of $1000W/m^2$ and temperature of 25 °c [12].

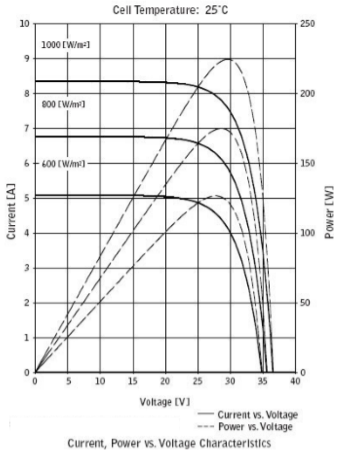

Figure 1. Characteristics of Photovoltaic

This curve is used to determine the performance of photovoltaic cells, modules and also arrays. The input for this curve is the solar irradiance and cell temperature. Moreover, the PV cell or module is operating at several voltage and current. Other than that, A PV module designed for large commercial and utility scale solar systems will have typically 72 PV cells. By increasing the number of solar cells the module voltage and wattage increases. Maximum power at knee point represents the maximum performance of a PV module. Other than that, the curve pattern will be change in case of different value of solar irradiance and same value of temperature or vice versa [13].

In this research, the selected PV module to be used is 120W Monocrystalline Photovoltaic Su-Kam Solar. The system specifications and ratings at standard test condition are shown in Table 2.

Table 2. Characteristics of 120W Monocrystalline Photovoltaic

No	Description	Abbreviation	Data
1	Nominal Power, PM	P_{MAX} (W)	120
2	Voltage at P_{MAX}	V_{PM} (V)	17.7
3	Current at P_{MAX}	I_{PM} (A)	6.8
4	Open Circuit Voltage	V_{OC} (V)	21.4
5	Short Circuit Voltage	I_{SC} (A)	7.2
6	Module Efficiency	%	15.68
7	Maximum System Voltage	V_{SYS} (V)	600
8	Module Voltage	V_{MODULE} (V)	12
9	Diode Rating	I_{DIODE} (A)	10

2.4. School Data

The information of SK Pintas Raya, Parit Raja, Batu Pahat, Johor is based on the site visit that had been conducted in early of this project. From the site visit, the collected data are consists of the school plan and monthly electricity bills that need to be use in this project. From the data collection, this project will be carry out with analyzing the current electricity cost and after proposed PV implementation at the school.

3. RESULTS AND ANALYSIS

This section will discuss on the methods used to analyze the potential of PV system implementation is SK Pintas Raya, Parit Raja, Batu Pahat, Johor and match the purpose of this research. The main purpose of this section is to explain about the steps in project planning for this project. The steps of the project planning are divided into four parts which are the NEM scheme, PV mounting design in school, PV module calculation and also the initial cost of this project. Then, analysis on the profit gain by the school also will be discussed at the end of this section. simulation of project, the PV performance analysis and also the PV efficiency analysis.

3.1. Project Planning

The project step is important as it involves a series of steps that determine how to achieve a particular goal. The project cycle is consisting of several stages which are identifying the project, design of project, implementation of project, evaluation of the project and also monitoring the project throughout the stages [14]. In this project, certain stages of project steps are involved for installation of PV System at SK Pintas Raya. This project is involving the identification of project, design of project, implementation of project and evaluation of the project. For project identification, this project is good to be carry out as Malaysia have high rate of solar irradiance. Project implementation and evaluation are basically related to the calculation of PV Module needed for this project and the profit from this project. The design of this project is related to the 2D design of the PV module on the school roof.

3.1.1. Net Energy Metering (NEM) Scheme

Net Energy Metering (NEM) is a scheme that introduced by Tenaga Nasional Berhad (TNB) for the consumers with own generation whose solar PV installed capacity is for self-consumption. In the event of excess generation, the energy is allowed to be exported to the grid [15]. The energy is sell to the distribution licensee such as TNB and the user will get paid. Therefore, it will be resulting in offsetting users' electricity bills.

This scheme is applicable to industry, commercial and domestic sectors as long as they are the customers of TNB. The installation also needs to be within their premises such as on the rooftops. Most importantly, the cost of solar power systems is decreasing annually so it is good for the user to gain benefits from this scheme.

In implementing Net Energy Metering Scheme, several steps need to be followed that compliance the regulations of PV implementation in Malaysia. Firstly, the applicant of NEM Scheme needs to fill up Form A and submit to the Sustainable Energy Development Authority (SEDA). Then, after the application is checked and approved, the application will be checked by TNB and proceed with installation if approved. If not approved, then the applicant will be informed by TNB.

During installation period, several steps need to be carry out such as the suitability of the meter used. If it is suitable for NEM Scheme, the applicants need to prepare for the declaration form for NEM Contracts. Lastly, the applicant need to sign off the contract of NEM Scheme implementation and can start to use PV under NEM Scheme.

3.1.2. PV Mounting at SK Pintas Raya

In this part, for assemble the PV on the roof, it need to refer from the school drawing plan. From the school plan, this is the roof plan for SK Pintas Raya Block A for the PV mounting purpose. The unit is in Meter (M). The PV Implementation design is Figure 2.

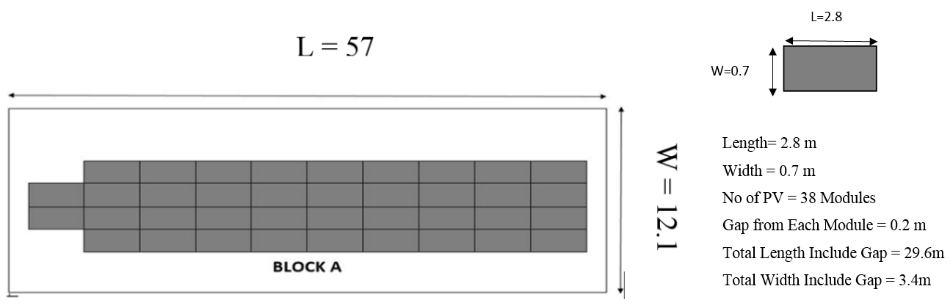

Figure 2. PV Mounting

3.1.3. Calculation on PV Modules

This part will discuss on the calculation of the electricity used by SK Pintas Raya which is Tariff B for Low Voltage Commercial Tariff. The data were collected and observed based on the electricity bills for the three consecutive month starting from May 2016 until July 2016. Below are the summary of the monthly electricity bills of SK Pintas Raya academic building.

Table 3. Monthly Electricity Bills

No	Month (2016)	Bills (RM)	Energy used (kWh)
1	May	686.10	1265
2	June	499.60	914
3	July	531.00	975

- Total energy used for three months are:

Average Energy Used = Total Energy Used / Months (1)
$(1265 + 914 + 975)/3$ = 1051 kWh
Monthly average energy usage is approximately 1000 kWh

- Total energy used every day by SK Pintas Raya:

Average Energy Used = Total Energy Used / Days (2)
$1000\ kWh/31\ days = 32.26\ kWh$
Daily average energy usage is 32kWh

To calculate the number of solar module that need to be used in this project, the solar availability in Malaysia need to be find out. Generally, sunlight is available at noon and around 8-10 hours' availability in Malaysia. But, it is not operated in full performance for the range of sun availability time and just assumed to 3.75 hours as the conservative value.

In this project, few steps of calculation need to be done to determine the numbers of module required. AC to DC conversion is important due to the commonly used of DC current equipment as the load while the solar system consumed the AC current. Firstly, the AC rating calculation is needed based on the data to convert the energy (kWh) into power (kW): -

AC rating = Average kWh per day / average sun hours per day (3)
$32\ kWh/3.75 hours = 8.53\ kW\ AC$

Next, the maximum power offered by the Monocrystalline Photovoltaic Su-Kam Solar Photovoltaic Module need to be recognized which is 120 W. It is called as the nameplate rating. Normally, in any types of conversion there will be some losses occur. Same goes to the conversion in the Photovoltaic systems from AC power to DC power. The losses or reduce of power is called as Derate Factor which is constantly 80% or 0.8. Therefore, in calculating the power in DC, the DC rating is shown in Equation 4:

DC rating = AC rating / Derate Factor (4)
$8.53\ kW\ AC/0.8 = 10.66\ kW\ DC$

The last step in this calculation part is to calculate the number of modules. To determine the number of modules that need to be used, the formula need is shown in Equation 5: -

Number of Modules = DC rating / Module Rating (5)
$10.66\ kW\ DC/120\ W = 89\ Modules$

So to make it easy for design, 89 solar modules are needed to supply 32kWh of energy every day. From this calculation, further analysis on the other project planning can be made.

3.1.4. Calculation on Cost of Implementation

This part will discuss on the total cost of implementing the solar panel in SK Pintas Raya. In project planning, cost calculation is important as it will determine the budget needed to complete the project. Basically, PV modules is sold in 2 ways either calculated price based on watt or another one is the fixed price. For 120 W PV price per watt, one (1) watt of power sold at USD 1 globally and RM 4.34 if converted into Malaysia Ringgit. So the cost of implementation of PV will be calculated.

USD 1 = RM 4.34
Module Price = Price Per Watt * Module Watt (6)
RM 4.34 * 120 Watt = RM 529.48
Price = RM 530.00

The number of modules needed by SK Pintas Raya to support the electricity in the school is 89 solar modules. Therefore:

Cost for Modules = Price Per Module * Number of Modules (7)
RM 530 * 89 modules = RM 47,170

Other than that, calculation of inverter and installation cost also need to be calculated. The cost for wiring is assumed to be 5% of the total module cost which is shown as below:

Other Cost = 5% * Module Cost (8)
5% x RM 47,170 = RM 2359

So, it can be concluded that the overall cost of PV system implementation needed by the school is RM 49,529.00.

3.2. Profit Analysis

Economics analysis is an important part in PV project because it is an indicator for the project recovery and project profit. Several ways can be used to determine the profit of the project. To determine the profitability of a PV project, some methods are commonly used which are payback period, net present value, net cash flow (NCF), and internal rate of return (IRR) [16]. In this project, only payback period will be used to analyze the project recovery and manually calculation for profit gain based on Standard Test Condition (STC) case and SK Pintas Raya case.

Payback period is defined as the years needed to recover the initial cost. It is good to have a project with shorter payback period because the investor can recover their initial cost in shorter period of time. Besides that, shorter payback period has greater project's liquidity. Therefore, it makes a project less risky in shorter period compared to a distant time project.

- Payback Period:

Average Monthly Electricity Charge = RM 572
Cost for System = RM 49,529.00
Payback = Cost of System / Average Bills (9)
RM 49,529 / RM 572= 86.59 months
Recovery period is 87 months

From the payback period calculation, the break-even point for this project is 87 months. So it needs 7 years and 3 months to recover the cost for the PV module. Therefore, this calculation shown the payback period needed by the school to implement this project. Next, in term of bills savings, the average monthly bills collected need to be analyze based on the lifespan of the PV module and further discuss in equation (10).

- Bills Saving:

Average Monthly Electricity Savings = RM 572.00
Average Lifespan of Monocrystalline Photovoltaic = 20 years
Savings = Monthly Savings * PV Lifespan (10)
RM 572 * 240 = RM 137,280.00

Throughout 20 years, it is expected that this project will have a huge savings which is RM137,280. From the saving, the profit gain from this project can be calculated as in equation (11).

- Profit Gain by SK Pintas Raya:

Profit = Savings – PV System Cost (11)
RM137,280 – RM 49,529 = RM 87,751

This project is expected to have at least RM87,751 of savings from paying the electricity bills after 20 years. So this is a good project to be implemented to the commercial building (school) in a long term as it saves the running cost of the electricity for SK Pintas Raya and become a profit to them.

4. CONCLUSION

Potential of solar PV system implementation by using 120W Monocrystalline Photovoltaic has been presented in this study. As the conclusion, this project have presented the steps involved in project planning of PV system implementation at school. From the steps involved, this project have determined the design of the PV mounting on the roof. Other than that, the calculation of initial cost that consists of the PV modules and the implementation process have been carry out.

From the calculation, it can be seen that this project need a huge amount of capital to begin the project. Although the initial cost is huge, the payback period is also being calculated and shown that it need at least 7 years to pay the cost. But, the lifespan of the PV module make this project become beneficial as the school can use the electricity without being charged for another 16 years. Therefore, the first purpose is achieved.

Secondly, the profit analysis also have been carry out in this project. Other than payback period, the profit gain by the school is also being calculated. From the calculation, it can be seen that in 20 years of implementation, the school can save up to RM 87,751.00 from paying the electricity bills. Therefore, it can be conclude that this project is become beneficial in a longer period of time. So, the second purpose is achieved.

Lastly, this project can be done in the future and achieve all the purpose stated earlier of this project. Therefore, it can be said that this project is beneficial to the society as it will counter the issue of high running cost of electricity as well as overcome the problem on the depletion of the non renewable resources.

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