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ECONOMICAL ANALYSIS OF GRID-CONNECTED BIPV AT UNIMAP BUILDING IN KUALA PERLIS, MALAYSIA

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ABSTRACT
Recently renewable energy (RE) technology burst the electricity generation in worldwide including Malaysia. The most popular renewable technology installation in Malaysia is solar PV. It is because Malaysia is located at equatorial region which makes it a very attractive region for potential solar radiation application technology. Kuala Perlis, which is one of the city in northern region of Malaysia, is geographically located at 6.4E 100.1N, the region receives annual solar radiation about 1797.1 W/m^2. Malaysia government has introduced the RE Bill which was approved in parliament in 2011 to enhance the energy produced by RE resources. From this bill, the electricity generated by photovoltaic (PV) will be paid up to RM 1.54 per kWh for non-individual producer if it is connected to the grid under feed-in (FiT) tariff scheme. This paper presents the economical study of grid connected BIPV system installation on top of roof Universiti Malaysia Perlis (UniMAP) laboratory buildings at Kuala Perlis. This study includes the sizing and design of PV system, total estimated annual energy yield and payback period analysis under FiT scheme. From this design, the annual energy yield connected to the grid is 313.54 MWh, estimated annual revenue is RM 0.35 mil and payback period is 7.12 years.

Keywords: Grid-connected, BIPV, FiT, Payback period, Photovoltaic.

1. INTRODUCTION

Solar energy is one of the RE resources. PV system is a technology which can generates electricity from solar energy. This technology enables a material or device to convert the energy contained in photon of light into an electrical voltage and current. Building-integrated PV (BIPV) system is classified as integration of PV system into the building architecture (Gilbert, 2013). BIPV system can be installed at different orientation and the tilt angle is depends on the environment and shading effect factor. The FiT is a method by Malaysian Government to encourage the private investor to catalyses the generation of RE up to 30 MW. The legislation is known as RE Power Purchase Agreement, it allows the electricity generated from the RE resources to be sold to power utilities e.g Tenaga Nasional Berhad (TNB) at a set premium price for a specific period (Sam & Mekhilef, 2009). This study focuses on the design of BIPV system on the roof top of UniMAP Laboratory Buildings which are situated at Kg. Wai, Perlis. The costing and pay-back period also will be analyzed to identify the return of investment (ROI) under FiT scheme incentive.

2. FEED IN TARIFF

The FiT is a mechanism to allow the private investor (individual or non-individual) to produce the electricity from RE resources such as solar, biomass, small hydro and sell it to the electricity utility with a set rate for the period of 21 years. FiT is not a subsidy or financed by tax reveneu but it is financed by the consumers who used the total monthly electricity energy more than 300 kWh. However, the passing of this cost is limited to only 1 % of the total electricity tariff. On 1st January 2014, the surchage is increace to 1.6 %. The FiT rate for PV technology is shown in Table 1 with effective period of 21 years. (KeTTHA, Kartina et al, 2014).

3. SYSTEM DESIGN

The main factor affecting the BIPV concept design is the area. The area of roof top is limited due to the shape of the roof. The equation for PV module efficiency is shown by Equation 1 (DGS, 2013).

$$\eta = \frac{P_{MPP}}{A\,x\,1000\,W/m^2} \qquad (1)$$

Where,
η = efficiency of PV module
P_{MPP} = Power module at STC
A = Area of PV module

The selection of inverter power rating is necessary to ensure that the selected inverter met the PV generation. This is defined by Equation 2 (DGS, 2013).

$$0.8\,x\,P_{PV} \langle P_{INV(DC)} \langle 1.2\,x\,P_{PV} \qquad (2)$$

Where,
P_{PV} = PV power generator (W)
$P_{INV(DC)}$ = Power inverter in DC (W)

The number of inverter is calculated using Equation 3.

$$\text{No. of inverter} = \frac{P_{PV}}{P_{INV}} \quad (3)$$

Based on (DGS, 2013), the connection of PV module in series will increase the voltage while the connection of PV module in parallel will increase the current. This is shown by Equation 4 and Equation 5.

$$\text{No of PV module in series} = \frac{V_{INV}}{V_{MOD}} \quad (4)$$

Table 1 Fit Rate of Photovoltaic for Non-Individual Installed in 2014 (SEDA, 2014)

Capacity of PV Installed	Fit rate (RM/kWh)
Installed capacity up to and including 4 kWp	1.0184
Installed capacity above 4 kWp, and up to 24 kWp	0.9936
Installed capacity above 24 kWp, and up to 72 kWp	0.8496
Installed capacity above 72 kWp, and up to 1 MWp	0.8208
Installed capacity above 1 MWp, and up to 10 MWp	0.6840
Installed capacity above 10 MWp and up to 30 MWp	0.6120
Additional for installation in building or building structures	+0.2153
Additional for use building materials	+0.2070
Additional for use locally manufactured or assembled solar PV modules	+0.0500
Additional for use locally manufactured or assembled solar inverters	+0.0500

Where,

V_{INV} = Maximum DC voltage of inverter (V)

V_{MOD} = Maximum voltage of PV module (V)

$$\text{No of PV string} = \frac{I_{INV}}{I_{MOD}} \quad (5)$$

Where,

I_{INV} = Maximum DC current of inverter (V)

I_{MOD} = Maximum current of PV module (V)

Payback period is a method to identify the investment of PV installation is beneficially. The payback period is calculated using Equation 6 (Kartina et al, 2014).

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Net annual benefit}} \quad (6)$$

Where,
Initial Investment = PV module + inverter + installation cost + other.
Net annual benefit = Revenue – Maintenance cost
Revenue = Income from selling power to the utility

Maintenance cost is assumed to be 1% of the initial investment.

4. SYSTEM DESIGN

UniMAP laboratory buildings are located at Kuala Perlis, Perlis, Malaysia with latitude and longitude of 6.4E, 100.1N respectively. These building are the double storey buildings with flat roofs and have an overall of 1821 m^2 area as shown in Figure 1.

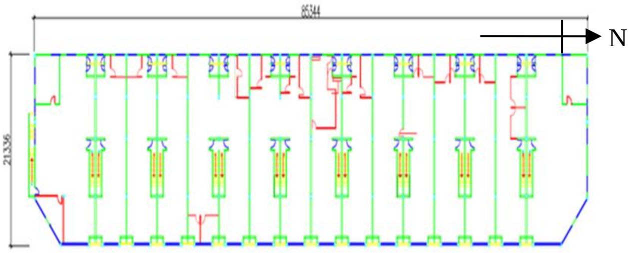

Figure 1 UniMAP laboratory building layout

The monthly average of solar radiation and temperature data at site location are shown in Table 2 below.

Table 2 Monthly Averages Solar Radiation and Temperature in Kuala Perlis, Perlis

MONTH	SOLAR RADIATION (W/m^2)	TEMPERATURE (°C)
JANUARY	160.8	27.6
FEBRUARY	156.3	28.3
MARCH	177.2	28.5
APRIL	166.0	28.7
MAY	155.3	28.5
JUNE	145.0	27.9
JULY	149.4	27.7
AUGUST	146.3	27.5
SEPTEMBER	139.1	27.2
OCTOBER	138.4	26.9
NOVEMBER	128.9	27.1
DECEMBER	134.6	27.1

5. METHODOLOGY

In this case study, the PV module selected is PANASONIC HIT 240 W based on the high efficiency. The specifications for selected PV module are shown in Table 3.

Table 3 Selected PV Module Specifications (Panasonic, 2014)

Manufacturer	Panasonic
Rated Power	240 W
Maximum current	5.51 A
Short circuit current	5.85 A
Maximum voltage	43.7 V
Open circuit voltage	52.4 V
Temperature coefficient (P_{max})	-0.30%/°C
Length	1580 mm
Width	798 mm

Base on the length and width of the selected PV module, there are several arrangement were used to install the PV modules as shown by Figures 2, 3, 4 and 5. The space between rows for each arrangement is same which is 1 meter, and the space at the first row is 2 meters.

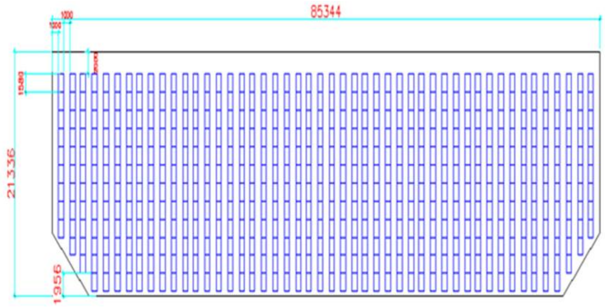

Figure 2 Type A: Horizontal arrangement with one row and one column.

Figure 3 Type B: Horizontal connection with two rows and two columns

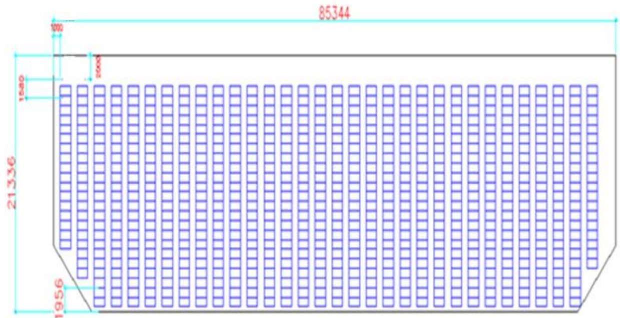

Figure 4 Type C: Vertical arrangement with one row and one column.

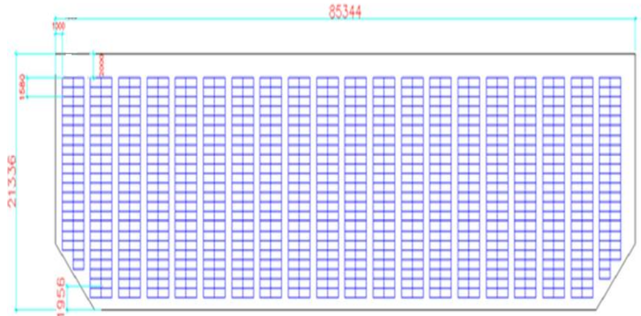

Figure 5 Type D: Vertical arrangement with two rows and two columns.

From these 4 arrangement types, the estimated power generated is shown in Table 4

Table 4 Estimated power of each design

Arrangement type	Numbers of PV Module	Estimated Power (kWp)
A	534	128.16
B	766	183.84
C	723	173.52
D	906	217.44

From the results in Table 4, type D arrangement was selected in this design because of its highest estimated power at the same area compared with other arrangement types. With the estimated power of type D arrangement, 217.44 kWp, the inverter was selected based on Equation 2 and Equation 3. The specification of selected inverter is shown in Table 5.

Table 5 Selected inverter specification (Siemens, 2014)

Manufacturer	SIEMENS
Rated input power (DC)	222 kW
Rated input current (DC)	486 A
Maximum DC voltage	900 V
Rated output power (AC)	210 kVA
Rated output current (AC)	306 A
Grid interface	3 phase /400V/ 50Hz

Rearrangement of the design was performed to suit the PV generator and inverter. Equation 4 and Equation 5 were used to select the number of PV module in series and the number of string as shown in Table 6. The tilt angle was set at 15 degree with facing to the south.

Table 6 PV Generator re-design

Number of PV module in series	15
Number of string	60
Total numbers of PV module	900
Total PV generation (STC)	216 p

6. RESULT

The estimated energy yield produced from this design was simulated using PVSYST software and is shown in Figure 6. The total energy produced by PV is 328.77 MWh and the total energy connected to the grid is 313.54 MWh.

It shows that the total loss is 4.63%. The Figure 7 shows the detailed energy losses of the system design. Based on (Kartina et al, 2014), the initial cost of PV installation is estimated at about RM 10,000 per kWp and maintenance cost is 1% from initial cost. From the simulation result, the payback period was calculated and is shown in Table 7.

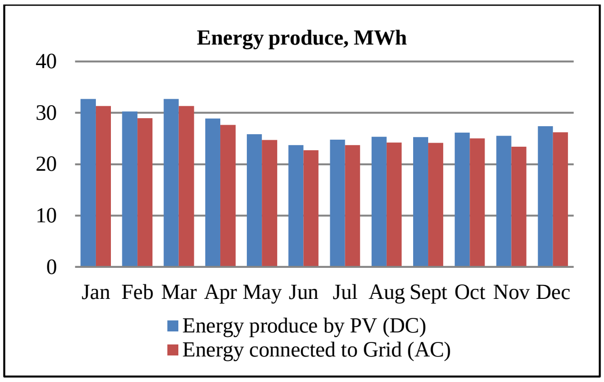

Figure 6 Energy produced by photovoltaic connected to the grid

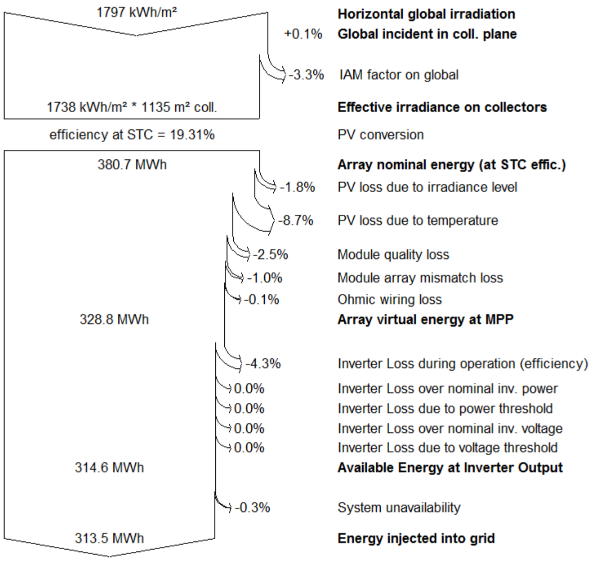

Figure 7 Energy losses diagram

Table 7 Payback Period

Initial investment	RM 2, 160, 000
Annual revenue	RM 324, 858
Maintenance Cost	RM 21,600
Payback Period	7.12ears

7. CONCLUSION

The FiT scheme rate is effective for 21 years. After 7 years and 2 months, which is payback period, UniMAP can gain revenue up to RM 4,509,029. It can beconsidered as a side income for the university. The installation of PV module on the rooftop of UniMAP buildings is a good project. As an educational organization, this would encourage the researcher to do more research on the optimization to reduce the energy losses and support the government incentive.

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