

Development of Web Application Package to Size a Grid Connected Photovoltaic System

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Abstract: This project focuses on the development of a Web Application Package for Sizing a Grid-Connected Photovoltaic (PV) System. The Web Application Package is designed to have the capability to size the load consumption and determine the usage of every component for the grid-connected PV system, costing, and total payback period. System sizing is vital to ensure all the equipment that is used not producing extra energy needed which is related to the cost and total payback period. This Web Application Package can show all the procedures system sizing from load consumption until the total payback period of the single-story terrace house. The Web Application Package is created by using the Google Sites with the Integration of Calconic. The generated result from the Web Application Package application needs to correspond with the manual calculation to ensure the process of sizing the grid-connected PV system can be used for this project. Hence, it is important to do the correct sizing because the total payback period depends on the total monthly savings and the total cost of the PV system installation.

Keywords: Web Application Package, Photovoltaic System, Grid Connected

1. Introduction

Renewable energy source typically refers to the energy that is both sustainable and infinite such as the sun, wind, and air [1]. These types of sources are always available without the need for a long period of time or energy renewal. When the word alternative energy is used, it usually refers to renewable energy sources as well. It refers to energy sources that are not as non-sustainable as the most regularly utilized non-sustainable sources such as coal. One of the most essential things contributing to the

country's long-term development is renewable energy. In Malaysia, solar, hydro and biomass are the most prominent renewable energy sources [2]-[3].

Solar electricity or also known as photovoltaic (PV) technology is one of the renewable technologies that has the potential to design a future electrical system that is clean, reliable, and scalable [4]. Due to its high efficiency, PV creates electricity from sunlight and transforms it into electrical energy [5]. However, one of the drawbacks of PV is, that it is not always dependable. This is because solar radiation varies and changes regularly due to the unpredictable nature of the sun and its reliance on weather and climate change. As a result, generated energy does not always match load demand. PV systems generate electrical energy from the amount of sunlight that is available on site [6]. Since there is more sunlight than rain in Malaysia, the weather is very perfect and conducive to the utilization of PV systems. Furthermore, grid-connected PV systems (GCPV) systems provide a variety of advantages, including modularity, low maintenance, and environmental friendliness [7], as well as the ability to sell excess energy to utilities [8], resulting in bill reduction.

The New Net Energy Metering 3.0 program (NEM 3.0) was introduced in 2020 to provide more opportunities for electricity consumers to install solar PV systems on the roofs of their premises to save on electricity bills [9]. To save cost, sizing the design of the PV system is the most important thing to ponder such as PV panels, inverter and load that must investigate thoroughly. It's vital to make sure the system is not over or undersized [10].

A Web Application Package is an interactive website made up of server-based programs that provide user interaction and a variety of other features [11]. There are a lot of advantages of Web Application Package such as the users can easily key in the data needed for the design of sizing grid-connected PV systems using a browser. In this project, a Web Application Package to size a grid-connected PV system, taking into account all PV system specifications, costing, load, and total payback period. As a result, users can apply the Web Application Package for PV system sizing.

2. Materials and Methods

The Web Application Package was developed by using Google Sites with Integration of Calconic that consists of a home page until the total payback period page that will be explained in this section. Moreover, the Web Application Package is being developed in conjunction with the computational sizing method that was previously performed to verify that the Web Application Package calculation results are accurate.

2.1 Web Application Package Development

This Web Application Package is divided into six tabs or pages which are the home page, load consumption analysis page, photovoltaic sizing page, tariff bill page, costing page, and total payback period page. For user convenience, a manual guide on each page is provided on how to utilize this website.

(a) Home page

Figure 1 shows the home page window as the main page of the website. It shows a lot of information regarding grid-connected photovoltaic systems such as a brief explanation of what is load consumption analysis, photovoltaic sizing, tariff calculation, costing and total payback period.

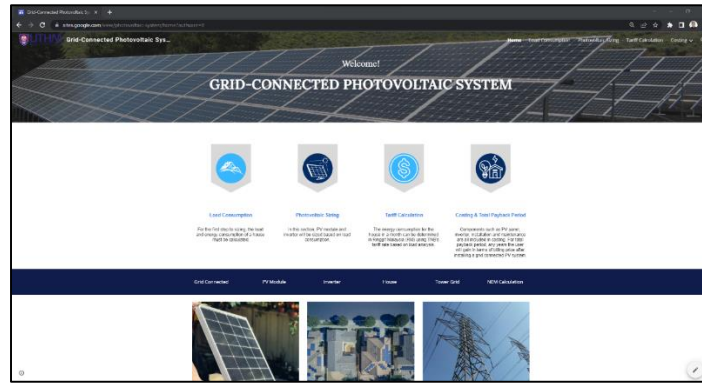


Figure 1: Home page

(b) Load Consumption Analysis Page

For the first step to sizing, the load and energy consumption must be calculated before continuing the next step. Below are the equations that used to find the daily and monthly energy consumption. It has five steps to be taken. First step is using the Eq. 1 [12] below to find the Total Connected Load.

$$\text{Total connected load} = \text{Estimated Power} \times \text{Quantity} \quad \text{Eq. 1}$$

Next, after the calculation of total connected load is finished, the second step is to calculate the Max Demand. Max Demand can be calculated by multiply Demand Factor with Total Connected Load which is in Equation 1 [12]. The calculation of Max Demand can be calculated by using Eq. 2 [13]-[14] below.

$$\text{Max Demand} = \text{Demand Factor} \times \text{Total connected load} \quad \text{Eq. 2}$$

Third step is to calculate the Total Max Demand which is the summation of all the type of load of Max Demand. The calculation of Total Max Demand can be calculated by using Eq. 3 [14].

$$\text{Total Max Demand} = \sum \text{Type of Load of Max Demand} \quad \text{Eq. 3}$$

Then, for the fourth step is to calculate the Daily Energy Consumption (Wh) which is the multiplication of Max Demand and Daily usage. The calculation of Daily Energy Consumption (Wh) can be calculated by using Eq. 4 [15].

$$\text{Daily Energy Consumption (Wh)} = \text{Max Demand} \times \text{Daily usage} \quad \text{Eq. 4}$$

Finally, the last step for the Load and Energy Consumption Calculation is to calculate Monthly Energy Consumption (kWh). The formula is Daily Energy Consumption multiply with 30 Days the divided by 1000 because of the prefix. The calculation of Monthly Energy Consumption (kWh) can be calculated by using Eq. 5 [16].

$$\text{Monthly Energy Consumption (kWh)} = \text{Daily Energy Consumption} \times 30 \text{ Days} \div 1000 \quad \text{Eq. 5}$$

The design of Web Application Package is implemented in the load consumption analysis page. Figure 2 illustrated the page.

Figure 2: Load Consumption Analysis page

After calculating overall energy use, the next step is to determine PV module sizing. Before using GCP, the rooftop area must first be assessed to establish how many panels may be installed. Based on the selected single-storey terrace house, the area of the house is 6×21 meter. Hence, on the rooftop can fit with four PV panels which take 5×2 meter. In this PV sizing, it has five steps of calculation which is Eq. 6 to 11 [17]-[18].

Step 1: $P_{out_{array}} = P_{PV} \times P_{guarantee} \times No.\ of\ panel$ Eq. 6
 Where,
 $P_{out_{array}}$ = Array guarantee power output
 P_{PV} = PV panel rated DC power output
 $P_{guarantee}$ = Manufacturer power guarantee

Step 2: $PV_{con} = P_{out_{array}} \times [(AVE_{temp} - STC) \times C_{temp}]$ Eq. 7
 $Temp_{out} = P_{out_{array}} - PV_{con}$
 Where,
 PV_{con} = PV consideration
 $Temp_{out}$ = Temperature – corrected array power output
 $P_{out_{array}}$ = Array guarantee power output
 AVE_{temp} = Array avg. operating temperature
 C_{temp} = Temperature coefficient for power
 STC = Standard Test Conditions

Step 3: $Net\ Array\ Pout = Temp_{out} - [Temp_{out} \times Wiring\ Losses]$ Eq. 8
 Where,
 $Net\ Array\ Pout$ = Net array power output
 $Temp_{out}$ = Temperature – corrected array power output

Step 4: $Inv.\ Pout_{AC} = Net\ Array\ Pout \times Inv_{eff} \times Inv_{MPPT}$ Eq. 9
 Where,
 $Inv.\ Pout_{AC}$ = Inverter maximum AC power output
 $Net\ Array\ Pout$ = Net array power output
 Inv_{eff} = Inverter power conversion efficiency

$$Inv_{MPPT} = \text{Inverter MPPT efficiency}$$

Step 5: Average Daily Energy Production:

Eq. 10

$$Pout_{ave} = Inv.Pout_{AC} \times Ave_{insolation}$$

Where,

$Pout_{ave}$ = Average Daily Energy Production

$Inv.Pout_{AC}$ = Inverter maximum AC power output

$Ave_{insolation}$ = Average Daily Insolation (PSH)

Monthly energy production:

Eq. 11

$$MEP = Pout_{ave} \times 30 \text{ Days}$$

Where,

MEP = Monthly energy production

$Pout_{ave}$ = Average Daily Energy Production

The interface of Web Application Package is also successfully implemented in the photovoltaic sizing page. Figure 3 demonstrated the page.

Step	Description	Value
1	PV Panel Rated DC Power Output (PPT)	0
	Manufacturer Power Guarantee (Pguarantee)	0.00
	Number of Panel in Array	0
	Array Guarantee Power Output (Parray)	0 W
2	Array Avg. Operating Temperature (dTarray)	0
	Temperature Coefficient for Power (Temp)	0.0000
	Standard Test Condition Temperature (STC)	0
	Temperature-Corrected Array Power Output (Tempout)	0 W
3	Array Wiring and Mismatch Losses	0.00
	Net Array Power Output	0 W
INVERTER SIZING		
4	Inverter Maximum Dc Power Rating	0
	Inverter Power Conversion efficiency	0.00
	Inverter MPPT Efficiency	0
	Inverter Maximum AC Power Output (PinvAC)	0 W
TOTAL DAILY & MONTHLY ENERGY PRODUCTION		
5	Average Daily Insolation (PSH)	0
	Average Daily Energy Production	0 Wh/day
	Monthly energy production	0 kWh

Figure 3: Photovoltaic Sizing

(d) Tariff Bill

Tariff bill calculation page is shown in Figure 4. This page displays the calculation of import and export energy consumption in kWh. It is also known as billing calculation because the tariff rate must adhere to TNB fixed rate. This page shows the total bill before and after the user install the grid-connected PV system and with total monthly saving in RM.

TOTAL IMPORT CHARGES			
Block kWh	Usage kWh	Rate (RM/kWh)	Amount (RM)
1-200	<input type="text" value="0"/>	<input type="text" value="0.218"/>	0.00
201-300	<input type="text" value="0"/>	<input type="text" value="0.334"/>	0.00
301-600	<input type="text" value="0"/>	<input type="text" value="0.515"/>	0.00
601-900	<input type="text" value="0"/>	<input type="text" value="0.545"/>	0.00
901 onwards	<input type="text" value="0"/>	<input type="text" value="0.571"/>	0.00
Total (import)	0	<input type="text" value="0"/>	0.00

TOTAL EXPORT CHARGES			
Block kWh	Usage kWh	Rate (RM/kWh)	Amount (RM)
1-200	<input type="text" value="0"/>	<input type="text" value="0.218"/>	0.00
201-300	<input type="text" value="0"/>	<input type="text" value="0.334"/>	0.00
301-600	<input type="text" value="0"/>	<input type="text" value="0.515"/>	0.00
601-900	<input type="text" value="0"/>	<input type="text" value="0.545"/>	0.00
901 onwards	<input type="text" value="0"/>	<input type="text" value="0.571"/>	0.00
Total (Export)	0	<input type="text" value="0"/>	0.00

TOTAL BILL AMOUNT		
Actual Bill	Expected Bill (RM)	Total Monthly Saving (RM)
0.00	0.00	0.00

Figure 4: Tariff Calculation page

(e) Costing

Figure 5 shows costing of overall system. This page requires the user to enter the price of the panel and inverter based on the size. Users should consider the cost of labour and wire while installing. It also includes the upkeep of the grid-connected PV system, which must be considered. The computation can be done with the help of Eq. 12 to 16 [18]-[20].

$$\text{PV Panel Price: Total PV Panel Price} = \text{Cost per panel} \times \text{Total needed panel} \quad \text{Eq. 12}$$

$$\text{Inverter Price: Total Inverter price} = \text{Inv. PoutDC} \quad \text{Eq. 13}$$

Where,

$$\text{Inv. PoutDC} = \text{Inverter maximum DC power}$$

$$\text{Installation Price: Total Labour price} = \text{Labour rate} \quad \text{Eq. 14}$$

$$\text{Wiring,} = \% 100 \times \sum (\text{PV panel} + \text{inverter} + \text{labour}) \text{ price}$$

Where,

Percentage is set by 30% of total price of panel, inverter, labour.

$$\text{Maintenance: Price Total Maintenance price} = 10\% \text{ of Installation Price} \quad \text{Eq. 15}$$

$$\text{Total Costing Price:} = \sum (\text{PV panel} + \text{Inverter} + \text{Labour} + \text{Inst.} + \text{Maintenance}) \text{ price} \quad \text{Eq. 16}$$

PV Panel	
Cost per panel (RM)	0
Total needed panel	0
Total	RM 0

Installation	
Labour (RM)	0
Wiring (%)	0
Total	RM 0

Inverter	
Inverter Maximum DC (W)	0
Total (RM)	0

Maintenance	
Total	RM 0

Total Costing Price

RM 0

Back
Next

Figure 5: Costing page

(f) Total Payback Period

Figure 6 shows the total payback period page. In the page, it shows the result of the total payback period that user need to know after the installation of the PV system using the Eq. 17 [19]. This page can show the billing price after installation of the system and investment, which is cost estimation and total payback period within the production energy from the PV system.

$$\text{Total Payback Period (years)} = \frac{\text{Total costing Price (RM)}}{\text{Total Monthly Saving (RM)}} \times \frac{1}{12 \text{ Months}} \quad \text{Eq. 17}$$

Actual monthly bill (RM)	0.00
Total bill after install PV (RM)	0.00
Total monthly saving (RM)	0.00
Cost estimation of PV system (RM)	0.00

TOTAL PAYBACK PERIOD **NaN**Years

Back

Figure 6: Total payback period page

3. Results and Discussion

In section 2 of sizing steps are utilized to size the grid-connected PV system at the terrace house. As expected, the Web Application Package will be able to size correctly with any value other than the value displayed. It is dependent on the user and the type of electrical load such as PV panel, inverter, labour. Any error in this Web Application Package can result in excessive energy production and raise the installation cost. The observation data from the single-story terrace house is shown in Table 1.

Table 1: Estimated load & energy consumptions

No.	Type of Load	Quantity	Max Demand	Daily Usage (hours/day)	Energy Consumption (Wh)
1	T8 LED Light	10	90	10	900
2	Table fan	4	32	10	320
3	Wall fan	1	45	8	360
4	Pedestal fan	2	80	12	960
5	Ceiling fan	1	60	18	1080
6	Laptop charger	10	365	5	1825
7	Refrigerator	1	200	24	4800
8	Water heater	1	1080	1	1080
9	Rice cooker	1	450	2	900
10	Phone charger	5	7.5	5	37.5
11	Washing machine	1	500	2	1000
12	Television	1	85	5	425
13	Kettle	1	1700	2	3400

Table 2 displays the PV panels that were chosen for the installation of a single-story terrace house. The data for the PV panel came from the datasheet. According to this observation, four panels are necessary to put a 1kWp PV system on the terrace house. For PV sizing, the calculations for computational sizing method and Web Application Package that obtained are the same.

Table 2: Photovoltaic sizing

Step	Description	Value
1	PV Panel Rated DC Power Output (P_{PV})	355 W
	Manufacturer Power Guarantee ($P_{guarantee}$)	0.97
	Number of Panel in Array	4
	Array Guarantee Power Output ($P_{out_{array}}$)	1377 W
2	Array Avg. Operating Temperature (AVE_{temp})	30°
	Temperature Coefficient for Power (C_{temp})	0.0036
	Standard Test Condition Temperature (STC)	25°
	Temperature-Corrected Array Power Output ($Temp_{out}$)	1352 W

3	Array Wiring and Mismatch Losses	0.03
	Net Array Power Output	1311 W
4	Inverter Maximum Dc Power Rating	1500 W
	Inverter Power Conversion Efficiency	0.93
	Inverter MPPT Efficiency	1
	Inverter Maximum AC Power Output ($Inv. Pout_{AC}$)	1219 W
5	Average Daily Insolation (PSH)	4
	Average Daily Energy Production	4876 Wh/day
	Monthly energy production	146 kWh

Table 3 illustrates the total cost of the PV system calculated by using computational sizing method and Web Application Package. This shows that the Web Application Package can be applied for costing because the value of price of PV panel, inverter, installation, maintenance, and overall cost are the same value for both methods. Meanwhile for tariff bill, the value achieved for both methods are the same too.

Table 3: Result of Costing compared with Web Application Package

Type of price	Computational Sizing Method Result (RM)	Web Application Package Result (RM)
PV Panel	2320.00	2320.00
Inverter	550.00	550.00
Installation	3721.00	3721.00
Maintenance	372.10	372.10
Overall	6963.00	6963.00

Table 4, it shows that the comparison between the results of computational sizing method and Web Application Package calculations for calculating the total payback period. For the other type of price of both methods, the values are the same except for the value of total payback period. The values are slightly difference because of the website detected some difference in terms of decimal places.

Table 4: Result of Total Payback Period compared with Web Application Package

Type of price	Computational Sizing Method Result (RM)	Web Application Package Result (RM)
Actual monthly bill	186.91	186.91
Total bill after install PV	111.57	111.57
Total monthly saving	75.34	75.34
Cost estimation of PV system	6963	6963
Total payback period	7.71	7.70

4. Conclusion

The results demonstrated that the Web Application Package can size a grid connected photovoltaic system. The Web Application Package has been integrated with all the sizing techniques and formulae. Furthermore, this Web Application Package can perform any value that the user enters on their own, such as the load consumption and any PV panel characteristics. Furthermore, this Web Application Package can compute the system approximate cost and total payback period. For future research, it is suggested that it can be modified on interface so that it can more friendly user. Additionally, to improve as it may be utilized not just for residences but also for industrial areas that use a lot of electricity.

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