Evolution in Electrical and Electronic Engineering Vol. 1 No. 1 (2020) 15 - 24
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Homepage: http://publisher.uthm.edu.my/proceeding/index.php/eeee
e-ISSN : 2756-8458

Development of Graphical User Interface (GUI) Platform for Sizing a Grid-Connected Photovoltaic (PV) System

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DOI: https://doi.org/10.30880/eeee.2020.01.01.003
Received 10 August 2020; Accepted 06 September 2020; Available online 30 October 2020

Abstract: The research presented in this project focuses on the development of a Graphical User Interface (GUI) platform for sizing a grid-connected Photovoltaic (PV) System. The GUI is designed to have the capability to sizing the load consumption and determine the usage of every component for the grid-connected PV system, costing and return on investment (ROI). System sizing is vital because to ensure all the equipment that is used not producing extra energy needed which related to the costing and ROI. This GUI can show all the procedures system sizing from load consumption until the return on investment of the single-storey terrace house. The GUI is created by using the MATLAB Software application, which is GUIDE. The generated result from GUI 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 total monthly saving and total cost of the PV system installation.

Keywords: GUI, PV System, ROI, Grid-Connected

1. Introduction

There are three primary sources of energy which are fossil fuel, nuclear resources and renewable resources. All of the sources provide electricity that has been used in daily life. Renewable energy (RE) has been known to the public nowadays. In a few years ago, RE becomes the most desirability to replace existing sources [1]. Solar, hydro-power, biomass and geothermal are included in renewable energy sources [2]. It is because Renewable Energy Sources (RES) has offer better clean environment compared to conventional energy sources that become a reason to combat energy crises [3], [4].

An adoption of using Photovoltaic (PV) now become the third highest installed in RE technology after hydro-power and wind [5]. It is because of the cost and the performance of PV produce energy from sunlight to electrical energy. The condition in Malaysia is ideal for PV system because there is

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more sunlight than rain [6]. In this project, it will focus more on PV energy by sizing every part such as PV panels, battery, inverter, load and analysis PV system with a grid-connected.

For the area where electricity from the grid is available such as a single-storey terrace house, it is better to combine the PV system with the grid. This combination is also known as a grid-connected PV system. This is more economical, especially with the initiatives from the Malaysian government such as the Net Energy Metering (NEM) system [7]. The factors to be considered for sizing is PV panel, inverter and load. The analysis will come out with full of size needed. Therefore, by sizing the design may help to setup configuration easily. It needs to be explicitly calculated in detail to avoid misuse [8]. Hence, with proper sizing and analysis, the designed PV system will not only be able to produce sufficient power to supply the load requirements, but also can give economic return value.

Furthermore, the Graphical User Interface (GUI) will provide what the sizing needed for the PV system at house residential with the grid-connected. This GUI will consider all specification in terms of PV system, costing, power output, and return on investment. The GUI can perform the sizing from the load consumption analysis until the return on investment that needed for the user to install grid-connected PV system for their house.

2. Materials and Methods

The Graphical User Interface (GUI) was made by using MATLAB Software which is GUIDE application. The development of the GUI is along with the manual calculation that has been calculated before to ensure the calculation from GUI itself show the correct result.

2.1 Graphical user interface

- Main menu (start)

The first part of this GUI platform is the Start tab as show in Figure 1. From the start, user can select the “Start” button to continue the GUI procedures that contains load consumption, PV array, tariff bill etc.

Figure 1: The Start tab

- Load Analysis

The load analysis tab is design for calculate the load consumption that user used for daily and a month. The total of load consumption is important for the tariff calculation to get the actual billing price by the energy used by user. The load consumption equations for this purpose are listed in Eq. 1 [9].

The load consumption

$$\Sigma EAC = \Sigma(Q \times PR \times t) \qquad \text{Eq.1}$$

Where,

E	= Total energy consumption
Q	= Quantity of electrical appliance
PR	= Power rating of electrical appliance
t	= Operating time of electrical appliance

The total of E which is the daily load usage then it will be times with 30 days and from there it produces the total load usage for a month in kWh. Eq. 2 is listed below.

$$MEC = \Sigma \mathrm{E} \times 30days \qquad \text{Eq. 2}$$

Where,

MEC	= Monthly energy consumption (kWh)
ΣE	= Total energy consumption (Wh/day)

The design of GUI can be done in load analysis tab. The tab window is illustrated in Figure 2.

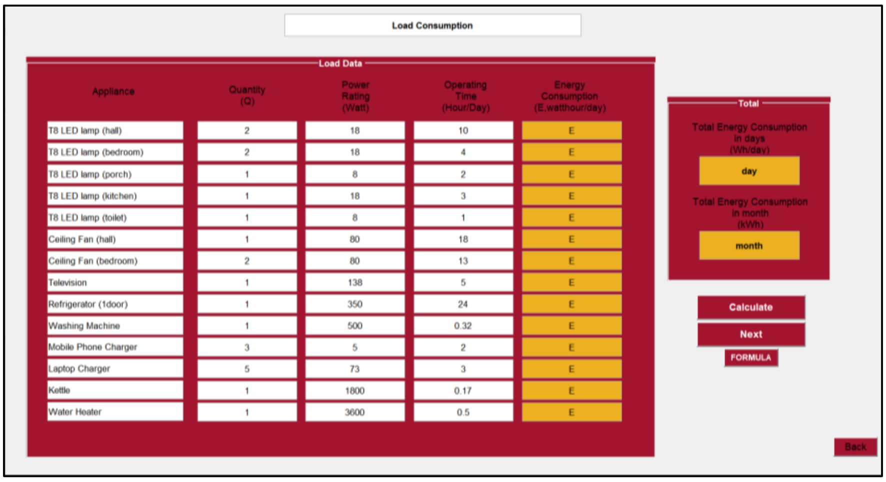

Figure 2: The load analysis tab

- Grid-connected photovoltaic

Next is the PV array tab which the section for calculate the PV according to the specification such as power rating, current, temperature, degree of orientation etc. In this tab user can insert the values of the PV panel and how many users want to used it. It will show the size of the inverter needed for the power produce by how many panels that user used. There are 4 steps needed to go through. The equation for this tab is listed below [9].

Step A:

$$Pout_{array} = P_{PV} \times P_{guarantee} \times No.panel \qquad \text{Eq.3}$$

Where,

$Pout_{array}$	= Array guarantee power output
P_{PV}	= PV panel rated DC power output
$P_{guarantee}$	= Manufacturer power guarantee

Step B:

$$PV_{con} = Pout_{array} \times \left[\left(Ave_{temp} - STC\right) \times C_{temp}\right] \quad \text{Eq. 4}$$

$$Temp_{out} = Pout_{array} - PV_{con} \quad \text{Eq. 5}$$

Where,

PV_{con}	= PV consideration
$Temp_{out}$	= Temperature-corrected array power output
$Pout_{array}$	= Array guarantee power output
Ave_{temp}	= Array avg. operating temperature
C_{temp}	= Temperature coefficient for power
STC	= Standard Test Conditions

Step C:

$$Net\ array\ Pout = Temp_{out} - [Temp_{out} \times wiring\ losses] \quad \text{Eq.6}$$

Where,

Net array Pout	= Net array power output
$Temp_{out}$	= Temperature-corrected array power output

Step D:

$$Inv.Pout_{AC} = Net\ array\ P_{out} \times Inv_{eff} \times Inv_{MPPT} \quad \text{Eq.7}$$

Where,

Inv. $Pout_{AC}$	= Inverter maximum AC power output
Net array Pout	= Net array power output
Inv_{eff}	= Inverter power conversion efficiency
Inv_{MPPT}	= Inverter MPPT efficiency

Average daily energy production

$$Pout_{ave} = Inv.Pout_{AC} \times Ave_{insolation} \quad \text{Eq.8}$$

Where,

$Pout_{ave}$	= Average Daily Energy Production
Inv. $Pout_{AC}$	= Inverter maximum AC power output
$Ave_{insolation}$	= Average Daily Insolation (PSH)

Monthly energy production

$$MEP = Pout_{ave} \times 30\ days \quad \text{Eq. 9}$$

Where,

MEP	= Monthly energy production
$Pout_{ave}$	= Average Daily Energy Production

Figure 3 shows the GUI tab the interactive PV system sizing purpose [9].

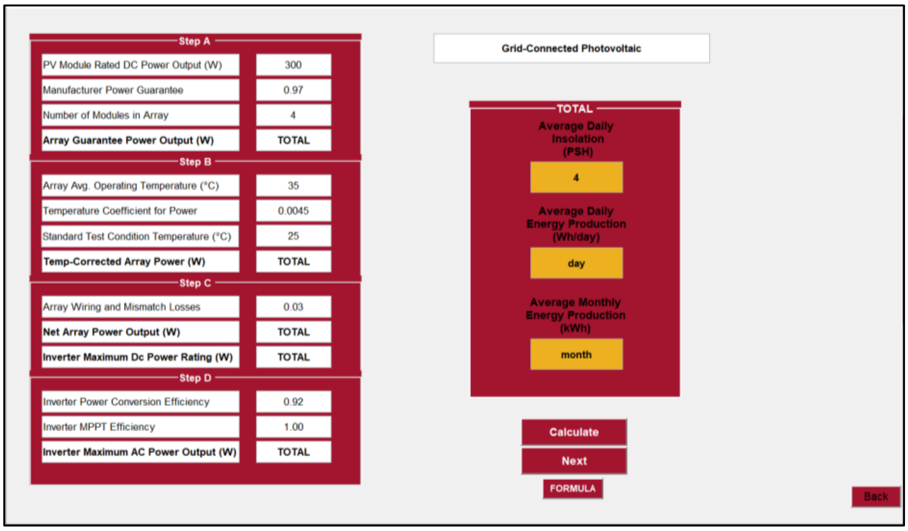

Figure 3: The grid-connected photovoltaic tab

- Tariff bill

This section is to calculate the import and export energy that being used and produces by the system. The usage will be divided by block and multiplied by the rate by the TNB. On the export column, the export will be at the higher block tariff from the import column. Figure 4 show the tariff bill from the GUI. In this tab, it will show the actual bill price and after bill price when the PV has been installed [10].

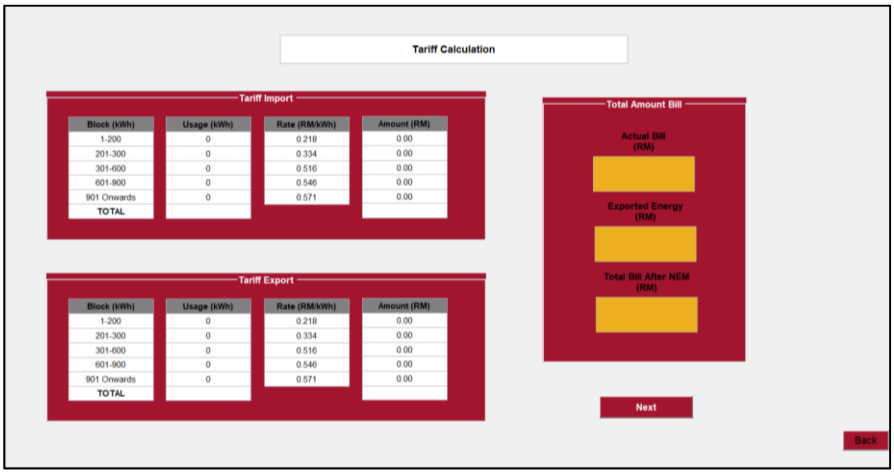

Figure 4: The tariff bill tab

- Costing

On this section, it shows the cost for installation grid-connected PV system. From the selected panel want to be used by user, this tab will automatically calculate for the price of PV panel, inverter, labour, wiring etc. All of the equipment needs to be count for user plan their budget by referring their specification of the system needed. It also included the calculation of annual maintenance for the system to ensure it work efficiently hence the purpose of this GUI to make user feel easy [11] . Figure 5 shows the outlook of GUI costing tab.

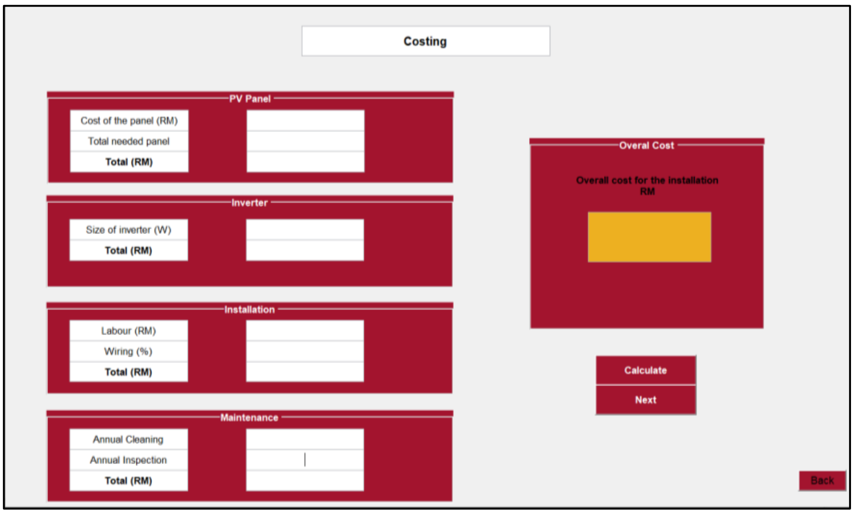

Figure 5: The costing tab

- Return on investment

This tab shows the overall result for this system which is from the load consumption until costing. Return on investment is important to calculate because user can install the system based on their budget and the specification needed. It also shows the payback period after the installation included the maintenance fees. Figure 6 show the GUI tab for return on investment [12].

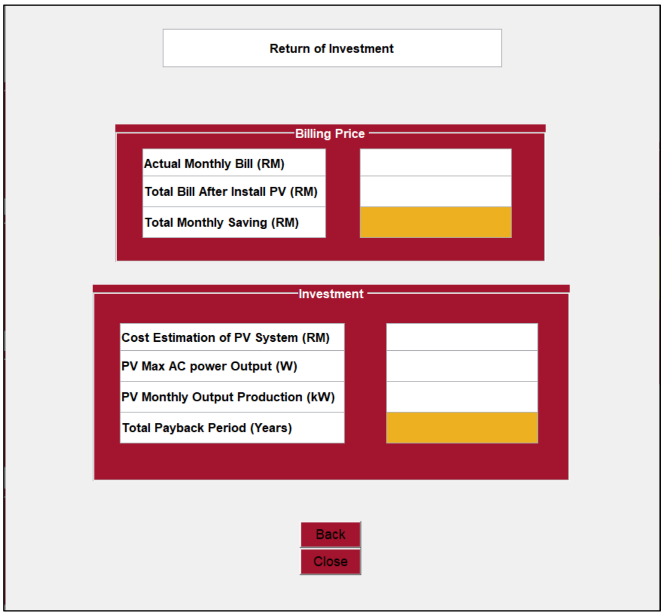

Figure 6: The return on investment tab

3. Results and Discussion

The sizing steps in Section 2 are used to sizing the grid-connected PV system at the terrace house. As expected, this GUI will be able to sizing correctly with any value apart from the value show. It depends on user and which type of electrical load, PV panel, inverter, labour etc. Any mistake from this GUI can cause the over energy produce and increase the cost of the installation. From the Table 1 shows below, that is the observation data from the single-storey terrace house.

Table 1: The estimated load consumption

No.	Electrical Loads	Quantity (Q)	Power Rating (Watt)	Operating Time (Hour/Day)	Energy Consumption (E, Watthour/Day)
1	T8 LED lamp (hall)	2	18	10	360
2	T8 LED lamp (bedroom)	2	18	4	144
3	T8 LED lamp (porch)	1	8	2	16
4	T8 LED lamp (kitchen)	1	18	3	54
5	T8 LED lamp (toilet)	1	8	1	8
6	Ceiling fan (hall)	1	80	18	1440
7	Ceiling fan (bedroom)	2	80	13	2080
8	Television	1	138	5	690
9	Refrigerator (1 door)	1	350	24	8400
10	Washing machine	1	500	0.32	160
11	Mobile phone charger	3	5	2	30
12	Laptop charger	5	73	3	1095
13	Kettle	1	1800	0.17	306
14	Water heater	1	3600	0.5	1800

Table 2 shows is the selected PV panel that be used for the installation of single-storey terrace house. The data for PV panel was refer from the datasheet. In this observation four panels is sufficient for the terrace house to install 1kWp PV system. By refer at the Table 1 and Table 2, the return on investment has been made by the GUI. Hence the manual calculation and the GUI produce the same value. The return on investment show in Figure 7.

Table 2: Grid-connected PV

Description	Step	
PV Panel Rated DC Power Output	A	300W
Manufacturer Power Guarantee		0.97
Number of Panel in Array		4
Array Guarantee Power Output		**1164W**
Array Avg. Operating Temperature	B	35°
Temperature Coefficient for Power		0.0045
Standard Test Condition		25°
Temperature-Corrected Array Power Output		**1112W**
Array Wiring and Mismatch Losses	C	0.03
Net Array Power Output		**1078W**
Inverter Maximum Dc Power Rating		**1200W**
Inverter Power Conversion Efficiency	D	0.92
Inverter MPPT Efficiency		1.00
Inverter Maximum AC Power Output		**992W**
Average Daily Insolation (PSH)		**4**
Average Daily Energy Production		**4 kWh/day**

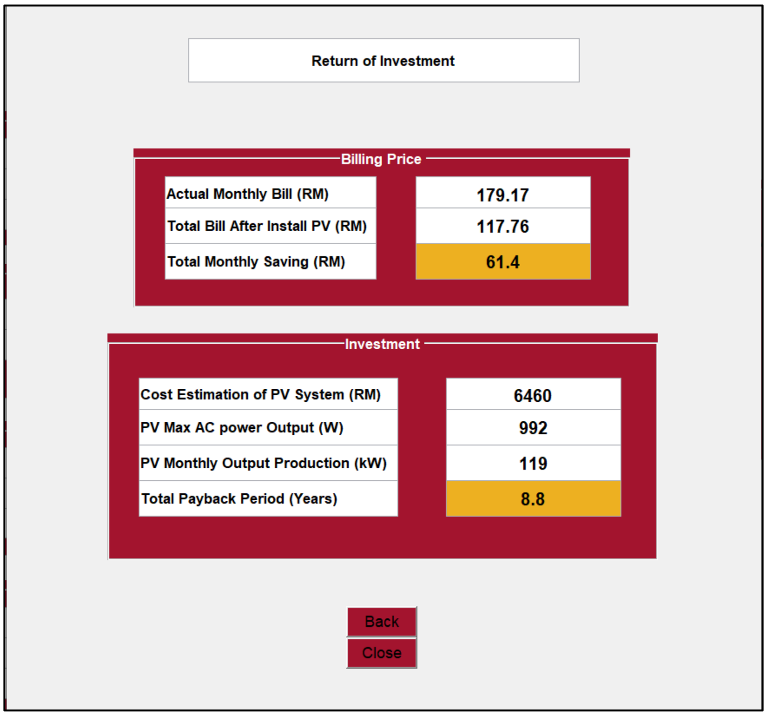

Figure 7: The return on investment tab

Based on the data, referring to the table figure shown above, it is important to do the correct sizing because the total payback period depends on total monthly saving and total cost of the PV installation.

4. Conclusion

The result have shown that the Graphical User Interface (GUI) platform has the ability to size the grid-connected photovoltaic system. All of sizing procedures and equations has been integrated with the GUI. In addition, this GUI can perform any value that user insert by their own such as the load consumption and any specifications of the PV panel. Moreover, this GUI platform can calculate the approximate cost of the system and ROI. For future research works, it is suggested to modify this GUI on mobile as application that can be download by everyone for their own usage or learning purpose. Besides, to improve as can be used not only for houses but can be used for industrial area that use more electricity.

Acknowledgement

The authors are grateful to the Green and Sustainable Energy (GSEnergy) Focus Group, Faculty of Electrical and Electronic Engineering, UniversitiTun Hussein Onn Malaysia (UTHM) for providing conducive research platform.

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