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Comparison Of Free Standing And Roof-Integrated Solar Power System For Automated Teller Machine (ATM)

Baruch Dominic Ekanem[1]
Foundation polytechnic Ikot Idem
Ikot Ekpene , Akwa Ibom State, Nigeria

Nnamonso O. Akpabio[2]
Department of Computer Engineering
Ibom Metropolitan Polytechnic, Uyo
Akwa Ibom State, Nigeria

Osita Nnoro[3]
Department of Electrical and Electronic Engineering
Imo State University, Owerri,
Imo State, Nigeria

***Abstract*— In this study, comparison of free standing and roof-integrated solar photovoltaic (PV) power system for Automated Teller Machine (ATM) is presented. Specially, this study seeks to compare the performance of two solar power systems; one with free standing PV (FSPV) module which has free circulation of air around the PV module and the second one with rooftop-integrated PV (RIPV) module where there is no enough air circulation around the PV module. The energy demand of 92.64 kWh per day with annual mean temperature of 24.9 °C and total annual total of monthly mean solar irradiation of 1717.2 kWh/n^2 are used for the simulation. The design configuration consists of system voltage of 48 V, maximum allowable loss of load of 1 %, days of autonomy of 3, battery bank made up of 208 battery units and PV array made up of 240 PV modules. For the FSPV the constant loss factor (Uc) is set at 29 w/m^2k whereas for the RIPV the constant loss factor (Uc) is set at 15 w/m^2k. The results show that the energy yield of the FSPV is higher with annual mean 3033.8 kWh with solar fraction of 0.991 (or 99.1 %) while the RIPV has 2969.4 kWh with solar fraction of 0.988 (or 98.8 %). In all, the results show that the FSPV mounting gives better performance than the RIPV mounting approach.**

Keywords*— *Free Standing Mounted PV, roof-integrated PV, solar power system, Automated Teller Machine (ATM), thermal loss

1. INTRODUCTION

Every year, more people across Nigeria are installing solar power systems as alternative to the power from the national grid [1,2,3]. This trend is also due to the increasing affordability of the solar power technologies [4] as well as the sharp rise in fossil fuel prices in the country [5]. Moreover, there is increasing advocacy for clean energy systems [6,7]. All these factors facilitate the growing adoption of various forms of solar photovoltaic (PV) power system across Nigeria.

When installing PV power system, the availability of space or lack of same may warrant rooftop integrated (RIPV) PV module mounting style [8,9] or the free standing PV (FSPV) mounting [10,11]. Each of the two approaches affect the PV system performances and hence the energy yield from the PV array. Accordingly, in this study simulation and comparison of free standing and roof-integrated solar PV power system for Automated Teller Machine (ATM) is presented. The study considered the cell temperature, thermal loss, the solar fraction, the energy yield and the PV module efficiency in each of the two PV mounting styles [12,13,14]. The PVSyst software [15] is used for the study to model the PV cell temperature in each of the two PV mounting styles and to conduct performance evaluation on the resultant PV power system. The essence of the study is to provide requisite information that will guide PV power designers and owners on the choice of PV mounting style and the impact on the performance of the solar power system.

2. METHODOLOGY

The cell temperature of the photovoltaic (PV) module affect the efficiency and energy yield of PV power system. Accordingly, this study seeks to compare the performance of two solar power systems; one with free standing PV module which has free circulation of air around the PV module and the second one with rooftop PV module where there is no enough air circulation around the PV module. The PV power system considered in this paper is for automatic teller machine (ATM) which has two ATMs and energy demand of 92.64 kWh per day when it operates all the 24 hours in a day. The energy demand profile modeled in PVSyst software is presented in Figure 1.

The installation site of the system at Uyo City Polytechnic, Uyo, Akwa Ibom with coordinates; latitude: 5.068414 and longitude: 7.937069 is presented in Google map screenshot in Figure 2 while the meteorological dataset for the case study site is presented in Figure 3 which shows annual mean temperature of 24.9 °C and total annual total of monthly mean solar irradiation of 1717.2 kWh/n^2.

The screenshot of the system design configuration dialogue box in PVSyst software is shown in Figure 4. It system voltage of 48 V, maximum allowable loss of load of 1 % , days of autonomy of 3, battery bank made up of 208 battery units and PV array made up of 240 PV modules. The details of the PV module are presented in Figure 5 while the details of the battery charge regulator are presented in Figure 6.

Table 1 The energy consumption data for the Automated Teller Machine (ATM)

S/N	Equipment Description	QTY	Power Rating (kW)	Duration (h)	Electrical Load (kW)	Energy Demand Per Day (kWh)
1	Automated Teller Machine (ATM)	2	0.7	24	1.4	33.6
2	AIR Conditioner	1	1.6	24	1.6	38.4
3	Light Bulb	6	0.09	24	0.54	12.96
4	Network Hub	1	0.32	24	0.32	7.68
	Total Energy Consumed				3.86	92.64

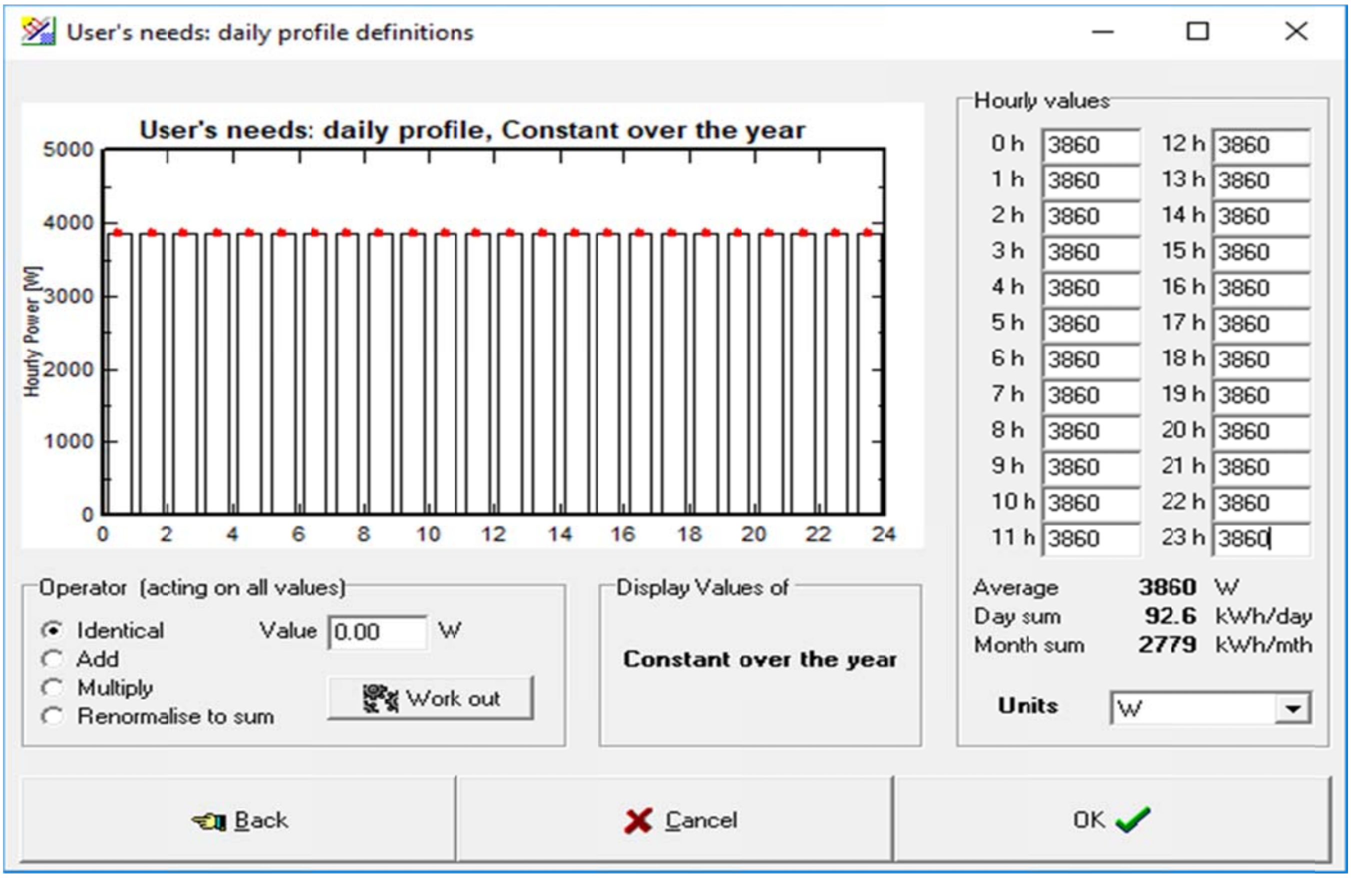


Figure 1 The energy demand profile modeled in PVSyst software

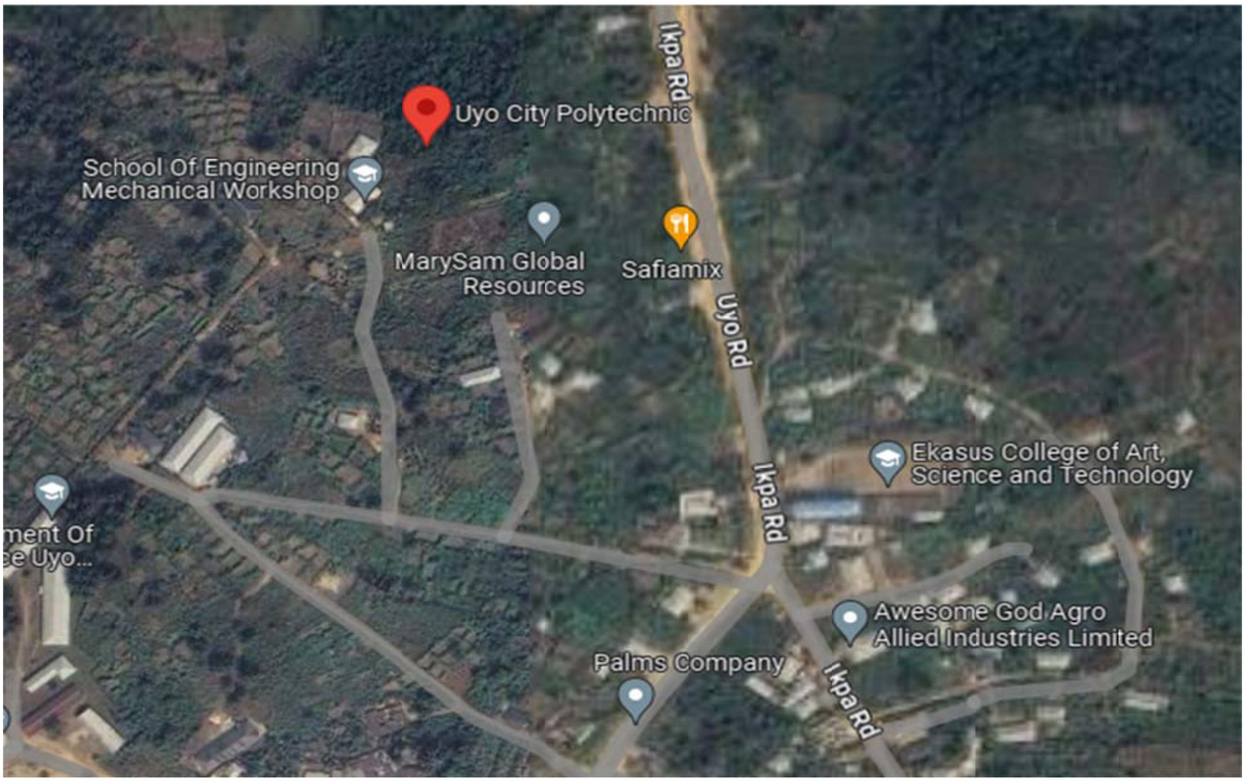


Figure 2 The installation site of the system at Uyo City Polytechnic, Uyo, Akwa Ibom with coordinates latitude:5.068414 and longitude:7.937069

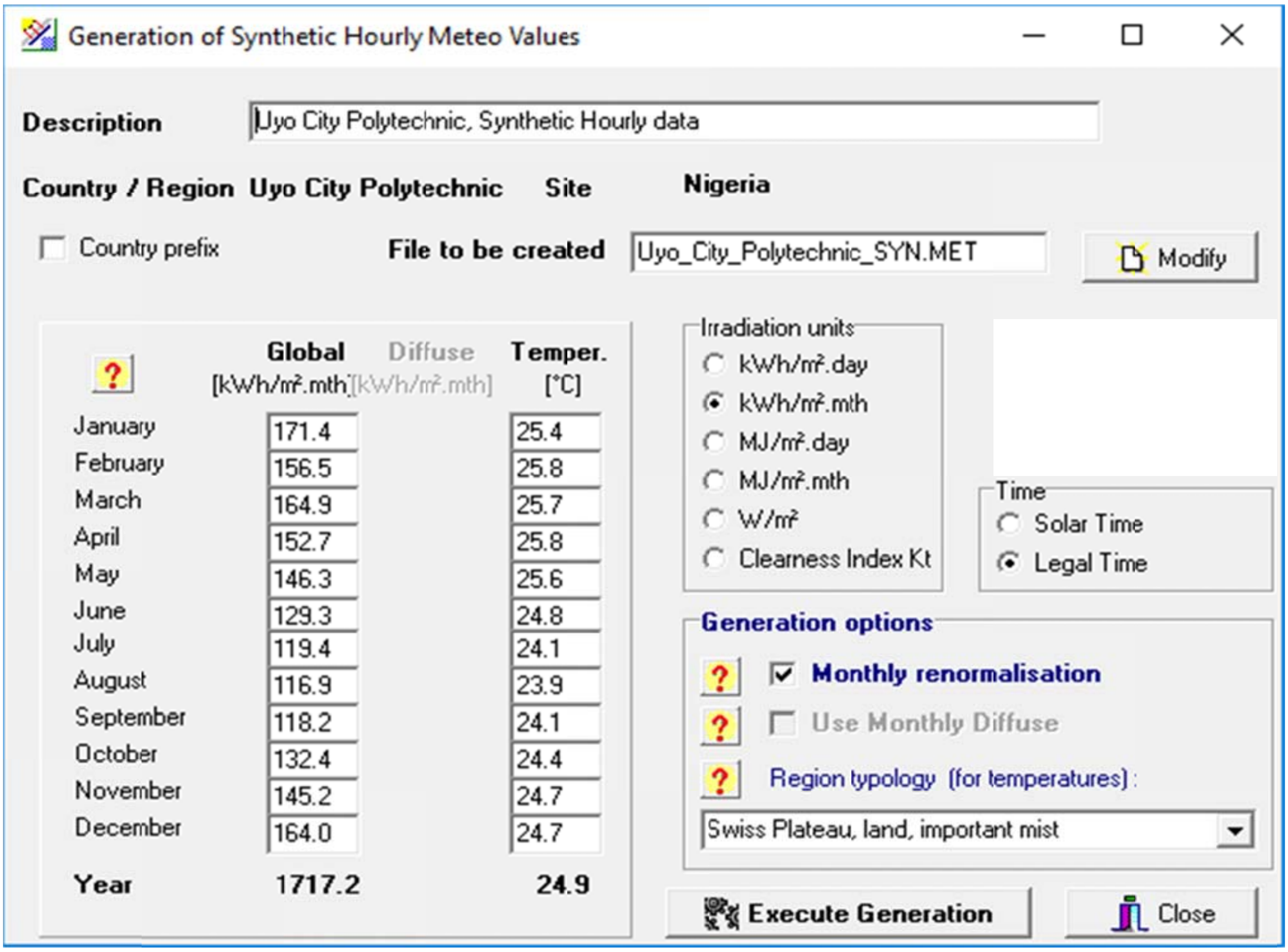


Figure 3 The meteorological dataset for the case study site

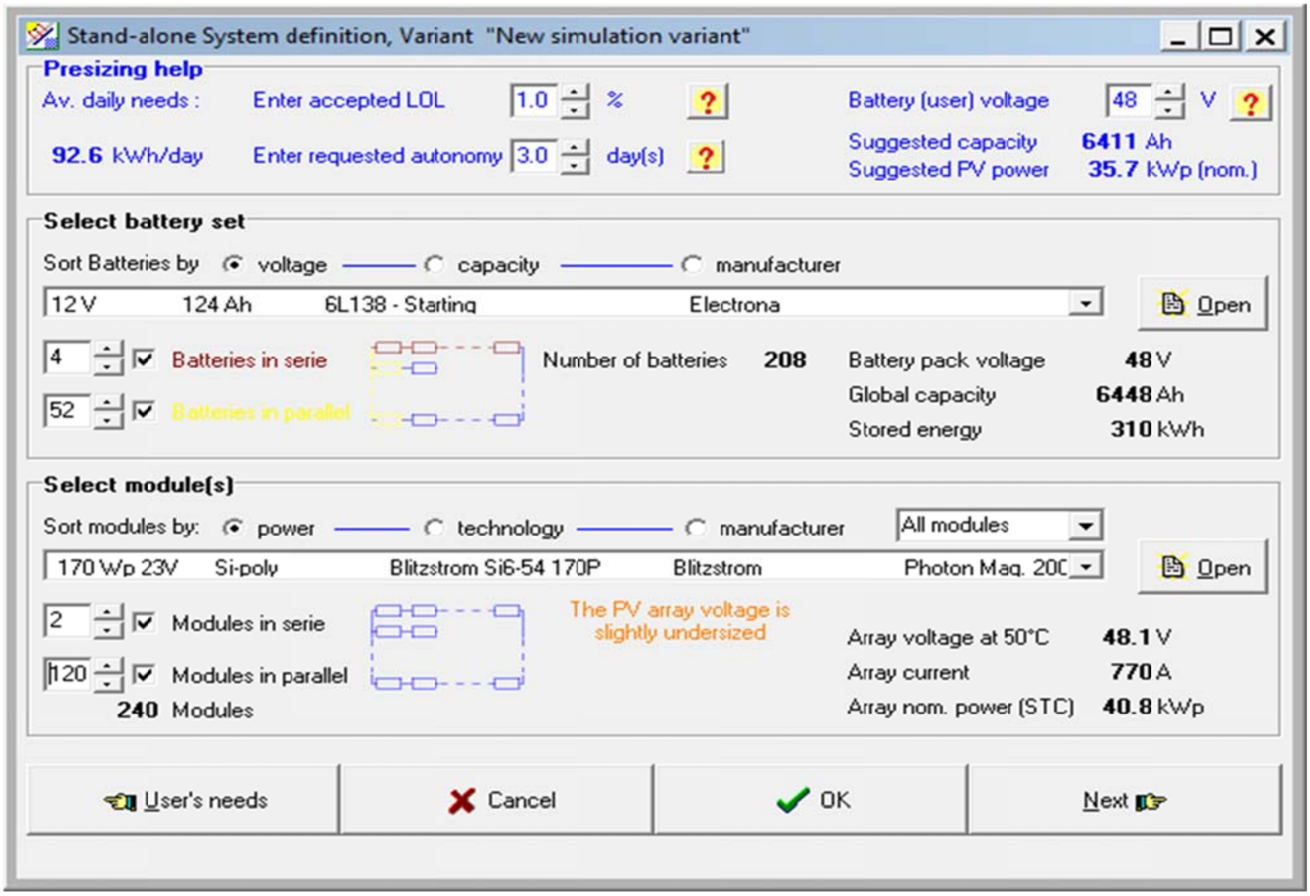


Figure 4 The system design configuration dialogue box in PVSyst software

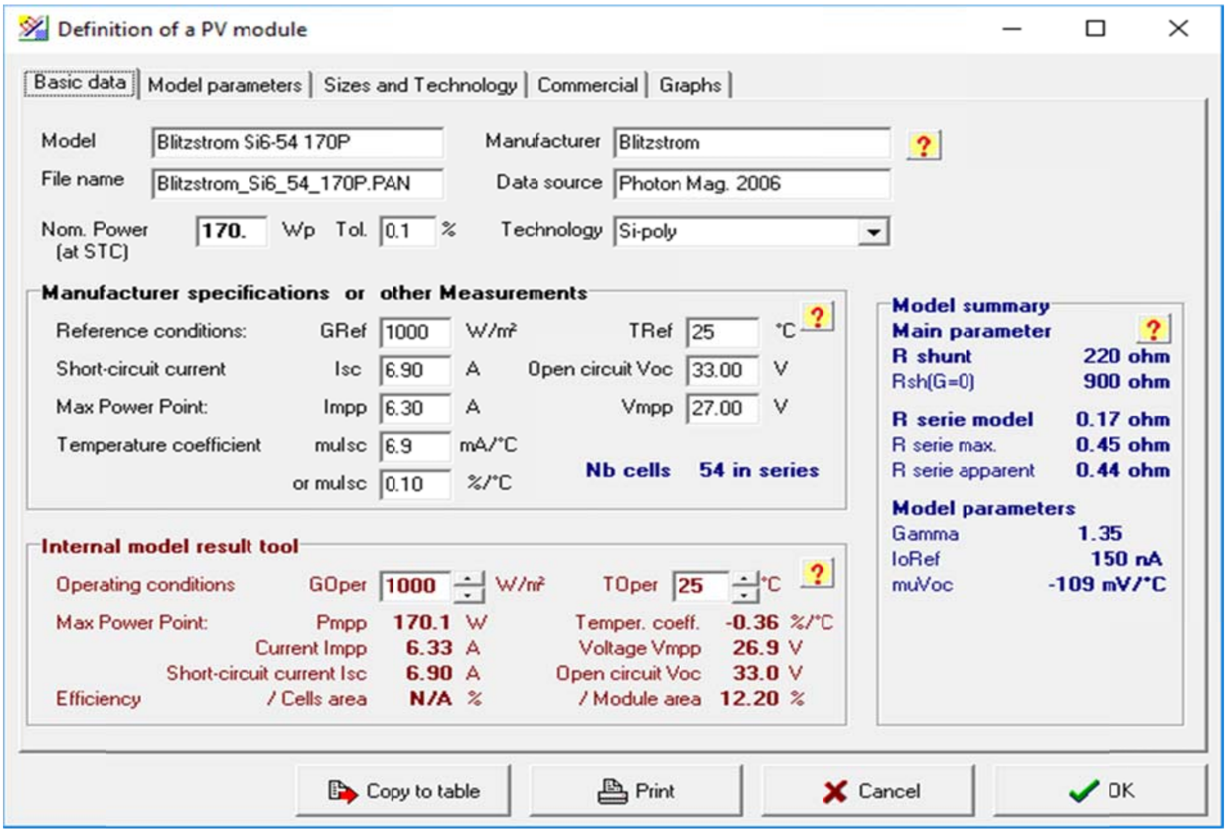


Figure 5 The details of the PV module

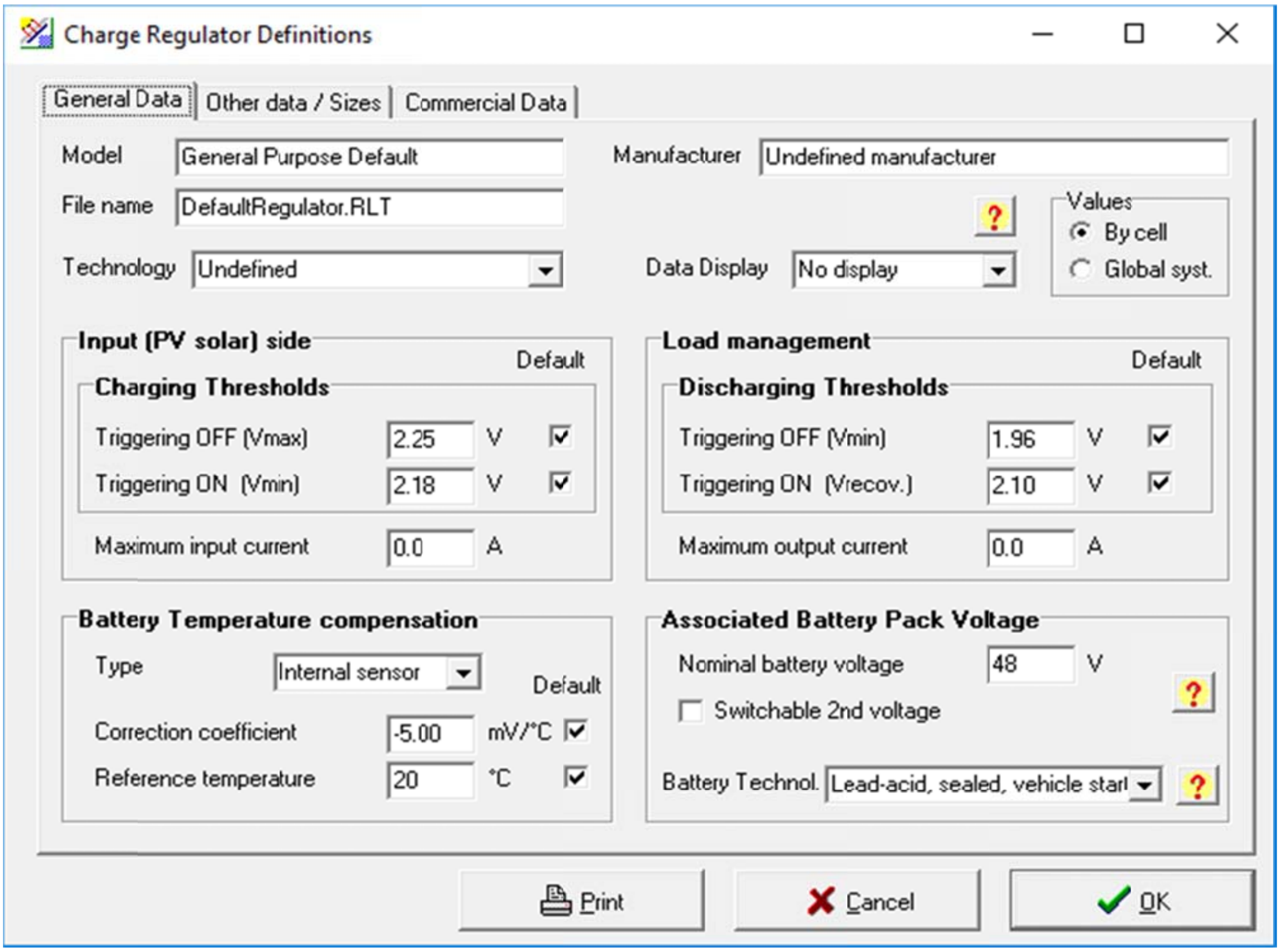


Figure 6 The details of the battery charge regulator

Specifically, the air circulation around the PV module affect the PV cell temperature. Again, the cell temperature results in thermal loss. The impact of the cell temperature is modeled in PVSyst in terms of thermal loss factor (U) as shown in Figure 7 and Figure 8. Alternatively, the impact of the cell temperature is modeled in PVSyst in terms of Normal Operating Collector Temperature (NOCT) factor as shown also in Figure 7 and Figure 8.

The PVSyst thermal factor settings for the free standing PV module with adequate air circulation around the PV module is shown in Figure 7 while the PVSyst thermal factor settings for the roof-integrated PV module without adequate air circulation around the PV module is shown in Figure 8. Notably, as shown in figure7 and in Figure 8, for the free standing PV module the constant loss factor (Uc) is set at 29 w/m^2k whereas for the roof-integrated PV module the constant loss factor (Uc) is set at 15 w/m^2k. Alternatively, in terms of the Normal Operating Collector Temperature (NOCT), for the free standing PV module the NOCT is set at 45 °C whereas for the roof-integrated PV module the NOCT is set at 68 °C.

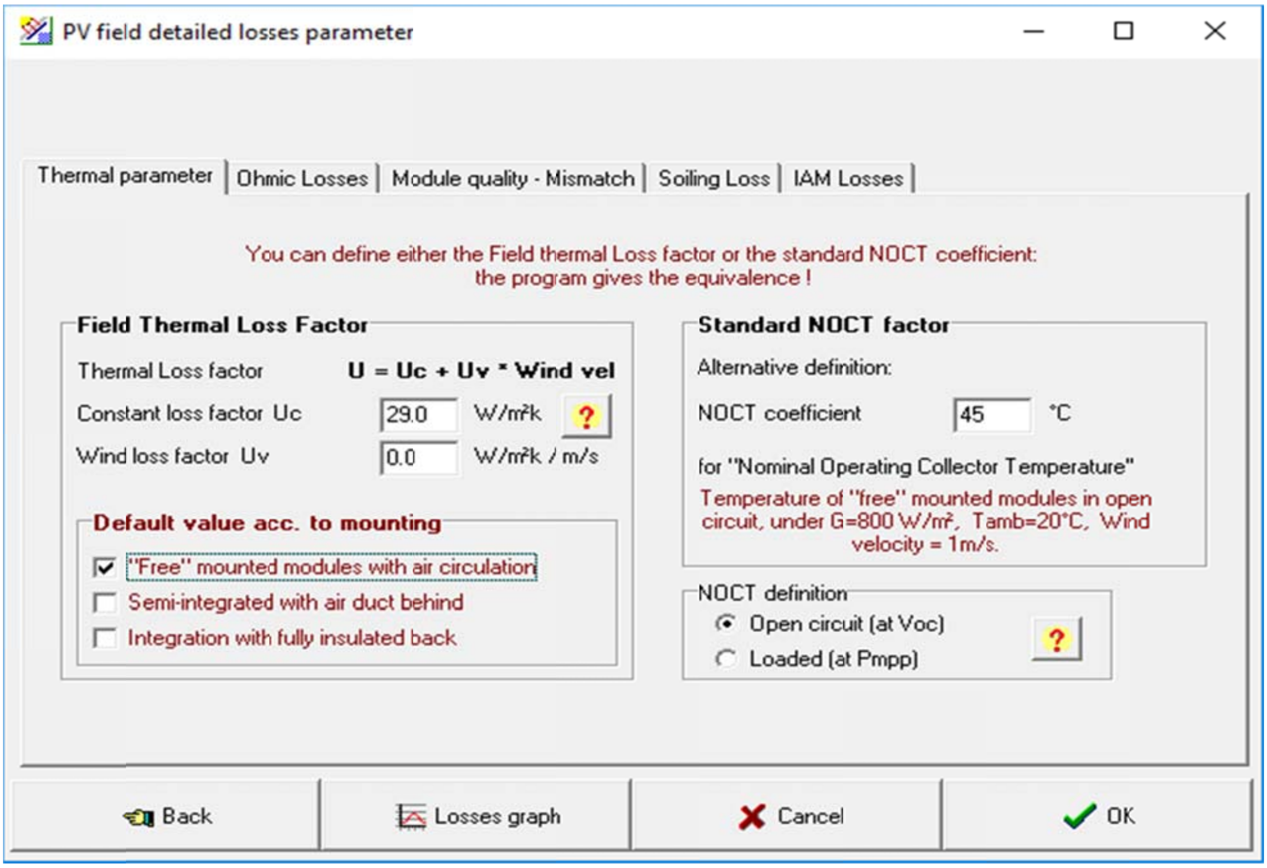


Figure 7 The PVSyst thermal factor settings for the free standing PV module with adequate air circulation around the PV module

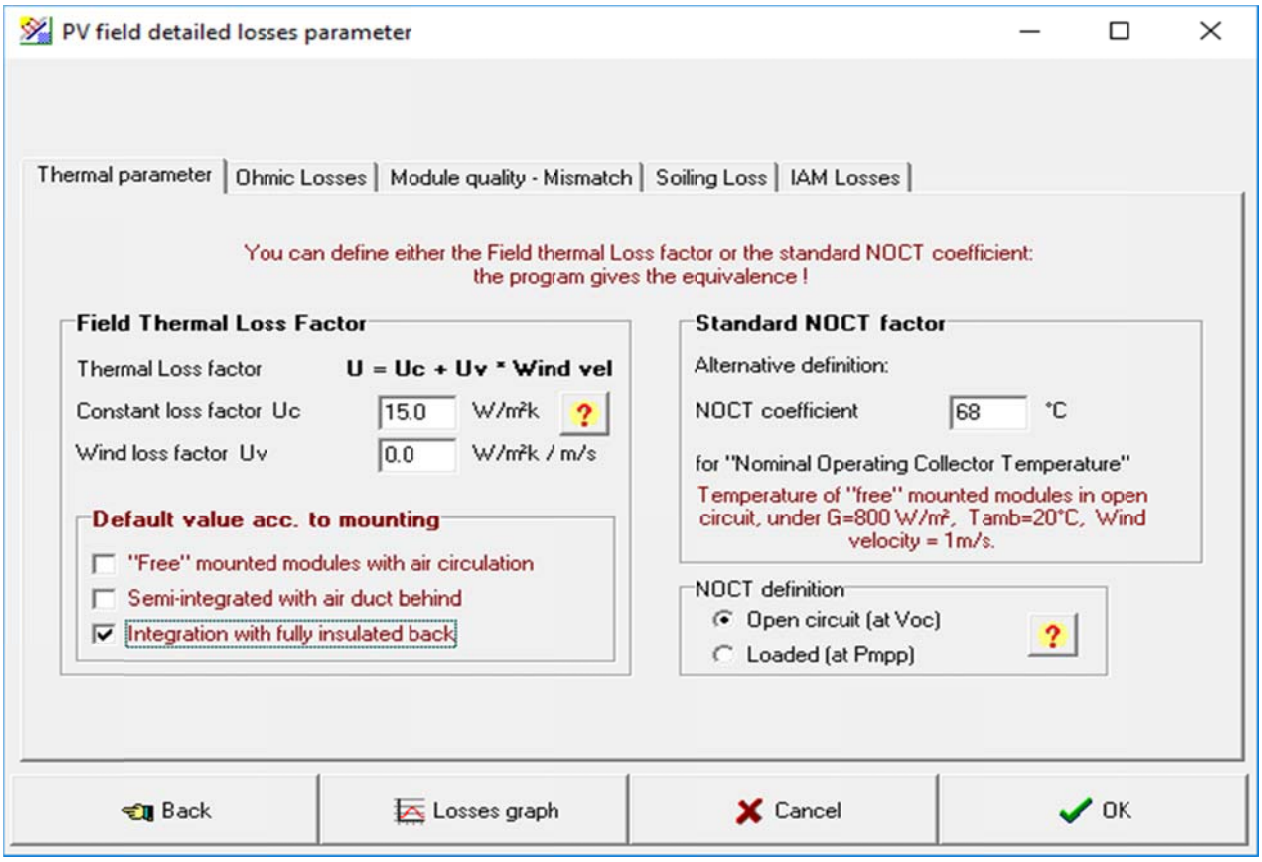


Figure 8 The PVSyst thermal factor settings for the roof-integrated PV module without adequate air circulation around the PV module

3. RESULTS AND DISCUSSION

The PVSyst software was used to simulate the operation of the PV power system and hence to evaluate the performance of the PV power system being studied. The simulations were conducted for the case I: free standing PV module and case II: roof-integrated PV module. The simulation results of the energy use, backup generator duration and fuel consumption for the free standing PV module with adequate air circulation around the PV module and for the roof-integrated PV module without adequate air circulation around the PV module are presneted in Figure 16.

Specifically, Figure 9 shwos the scatter plot of the energy yield of the PV array per month, EArray (kWH) for the case I: free standing PV module and case II: roof-integrated PV module. The graph shows that the energy yield of the case I: free standing PV(FSPV) module is higher with annual mean value of 3033.8 kWh while the case II: roof-integrated PV(RIPV) module has annual mean value of 2969.4 kWh. Again, as show in Figure10, the FSPV module also has higher solar fraction with annual mean value of 0.991 (or 99.1 %) while RIPV module has annual mean value of 0.988 (or 98.8 %).

The results show that the loss of load or missing energy occurred in the month of August alone. Hence, the free standing PV module has backup generator energy supply of 237.7 kWh in the month of August (Figure 11) with backup generator power supply duration of 79 hours (Figure 12) and backup generator power supply fuel consumption of 143 liters (Figure 13). On the other hand, the roof-integrated PV module has backup generator energy supply of 369.5 kWh in the month of August (Figure 11), with backup generator power supply duration of 123 hours (Figure 12)and backup generator power supply fuel consumption of 222 liter (Figure 13).

In addition, Figure 14 shows the scatter plot of the cell temperature of the PV array per month, for the case I: free standing PV module and case II: roof-integrated PV module. The graph shows that the cell temperature of the case I: free standing PV(FSPV) module is lower with annual mean value of 36.48 **°C** while the case II: roof-integrated PV(RIPV) module has higher annual mean value of 49.74 **°C**. The lower mean cell temperature of the FSPV resulted in higher PV cell efficiency with annual mean value of 6.29 % (as shown in Figure 15) and lower thermal loss with annual mean value of 469.06 kWh (as shown in Figure 16).On the other hand, the higher mean cell temperature of the RIPV resulted in lower PV cell efficiency with annual mean value of 6.15 % (as shown in Figure 15) and higher thermal loss with annual mean value of 826.42 kWh (as shown in Figure 16). In all, the results show that the FSPV mounting gives better performance than the RIPV mounting approach.

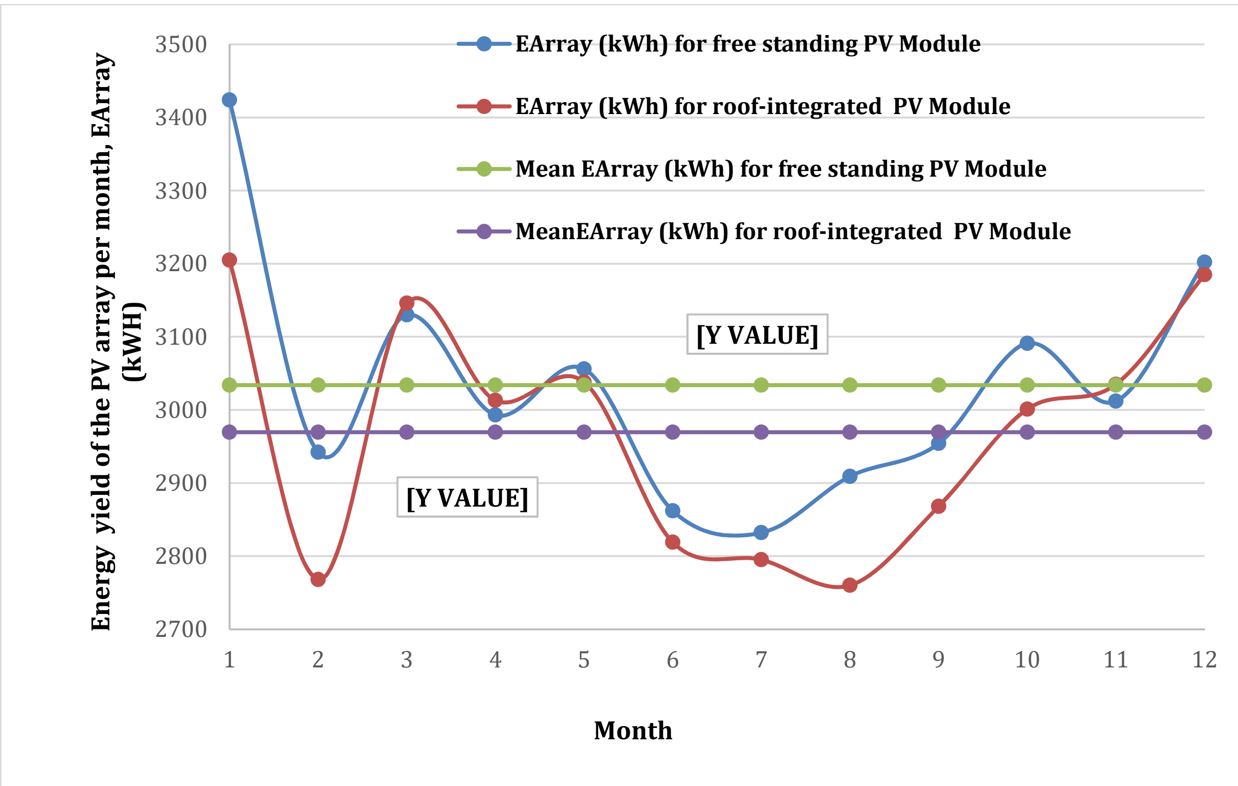


Figure 9 The scatter plot of the energy yield of the PV array per month, EArray (kWH)

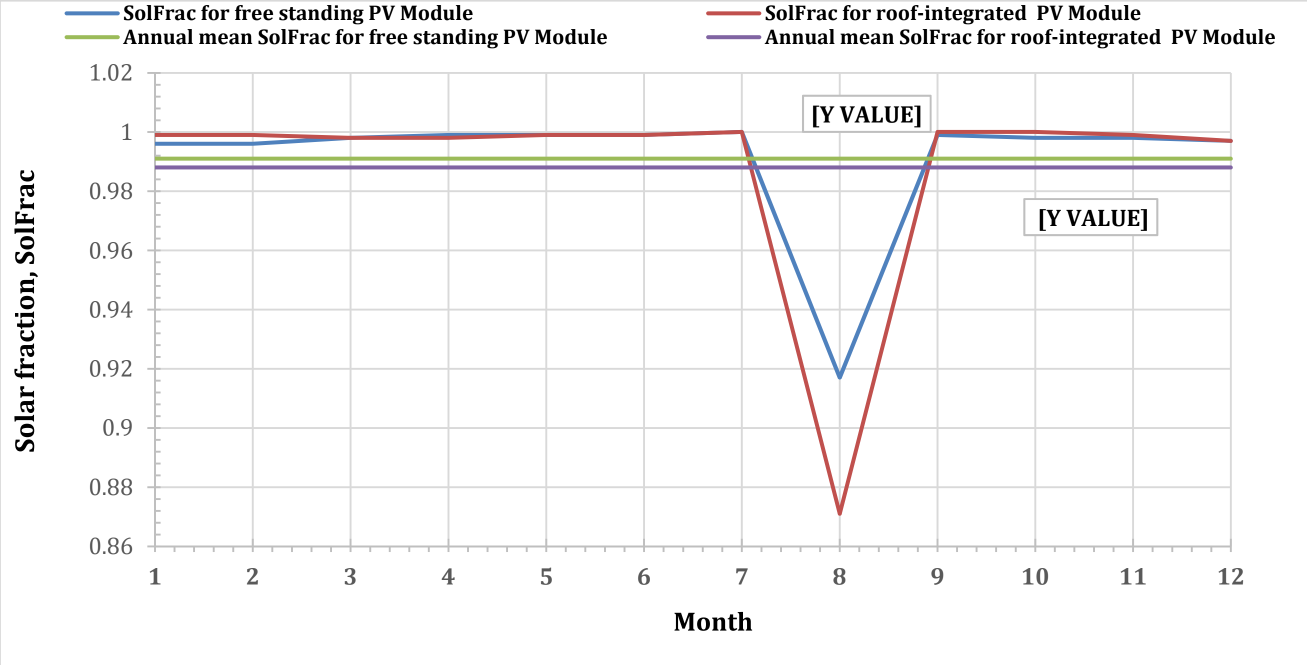
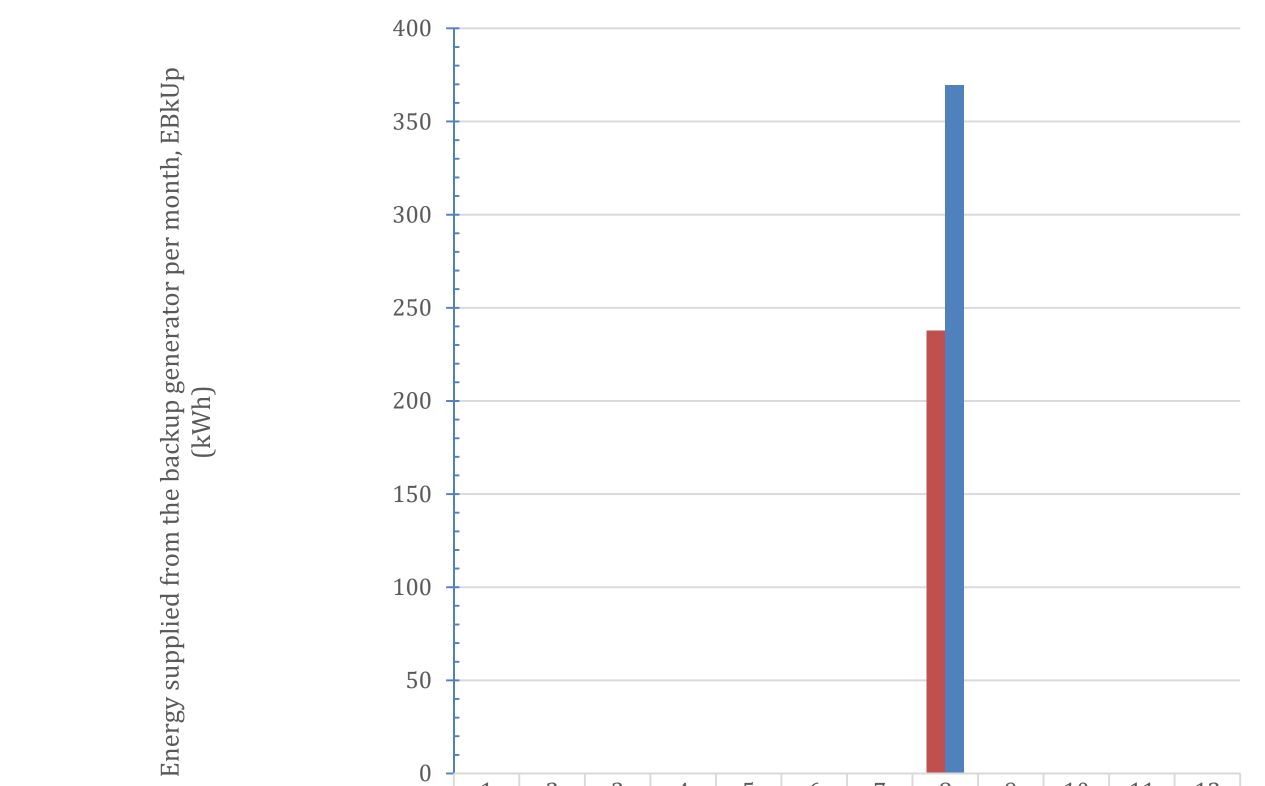
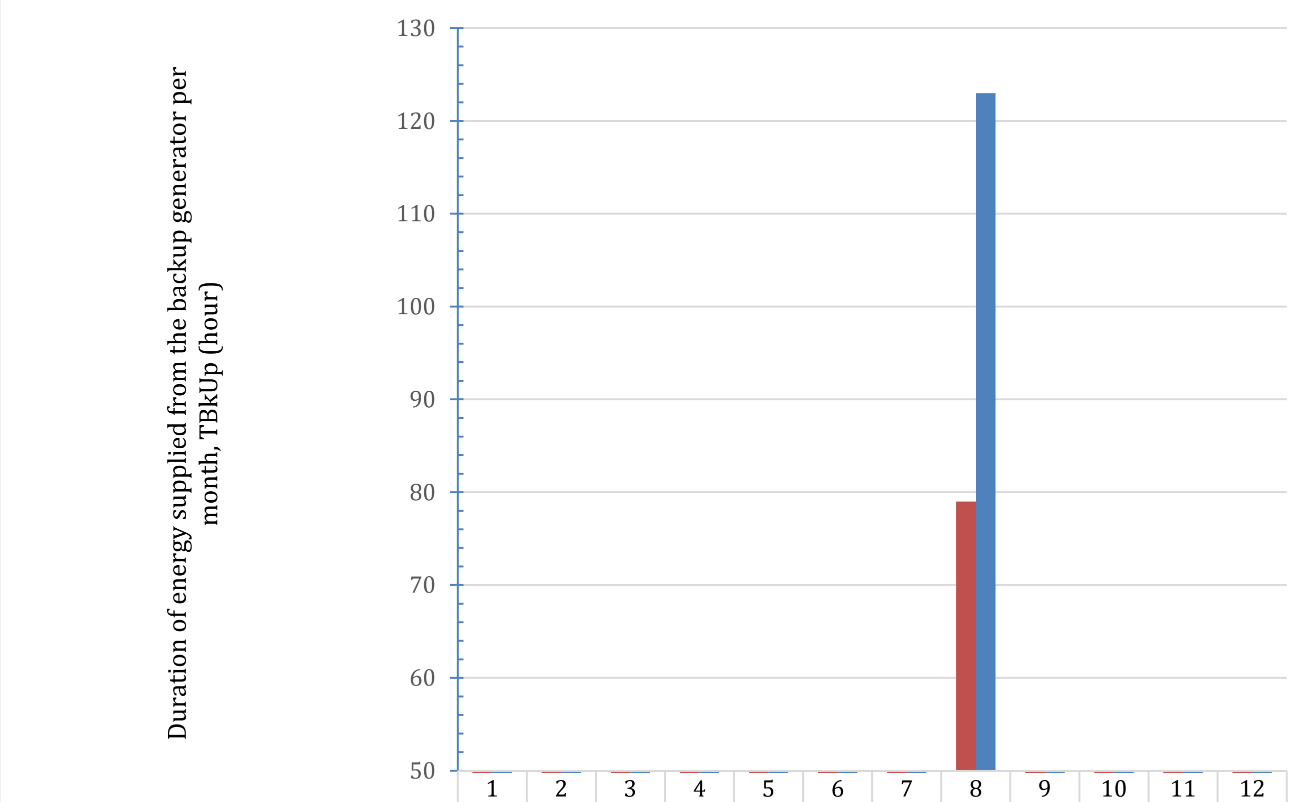


Figure 10 The scatter plot of the solar fraction, SolFrac



	1	2	3	4	5	6	7	8	9	10	11	12
EBkUp (kWh) for free standing PV Module	0	0	0	0	0	0	0	237.7	0	0	0	0
EBkUp (kWh) for roof-integrated PV Module	0	0	0	0	0	0	0	369.5	0	0	0	0

Figure 11 The bar chart of the energy supplied from the backup generator per month, EBkUp (kWh)



	1	2	3	4	5	6	7	8	9	10	11	12
TBkUp (hour) for free standing PV Module	0	0	0	0	0	0	0	79	0	0	0	0
TBkUp (hour) for roof-integrated PV Module	0	0	0	0	0	0	0	123	0	0	0	0

Figure 12 Bar chart of the duration of energy supplied from the backup generator per month, TBkUp (hour)

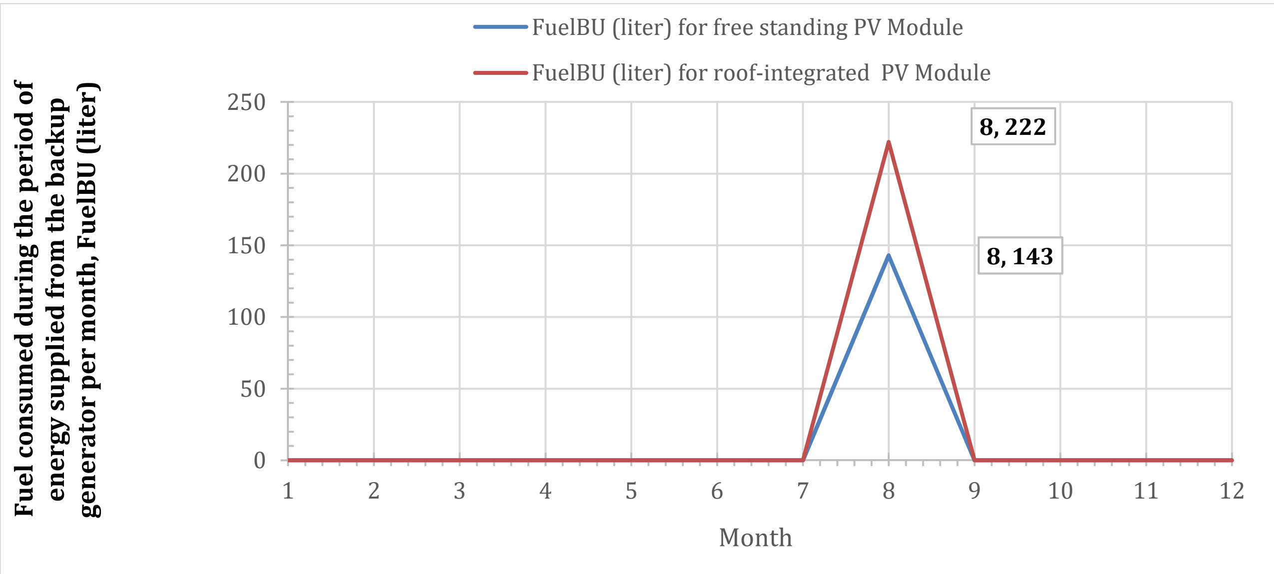


Figure 13 The scatter plot of the fuel consumed during the period of energy supplied from the backup generator per month, FuelBU (liter)

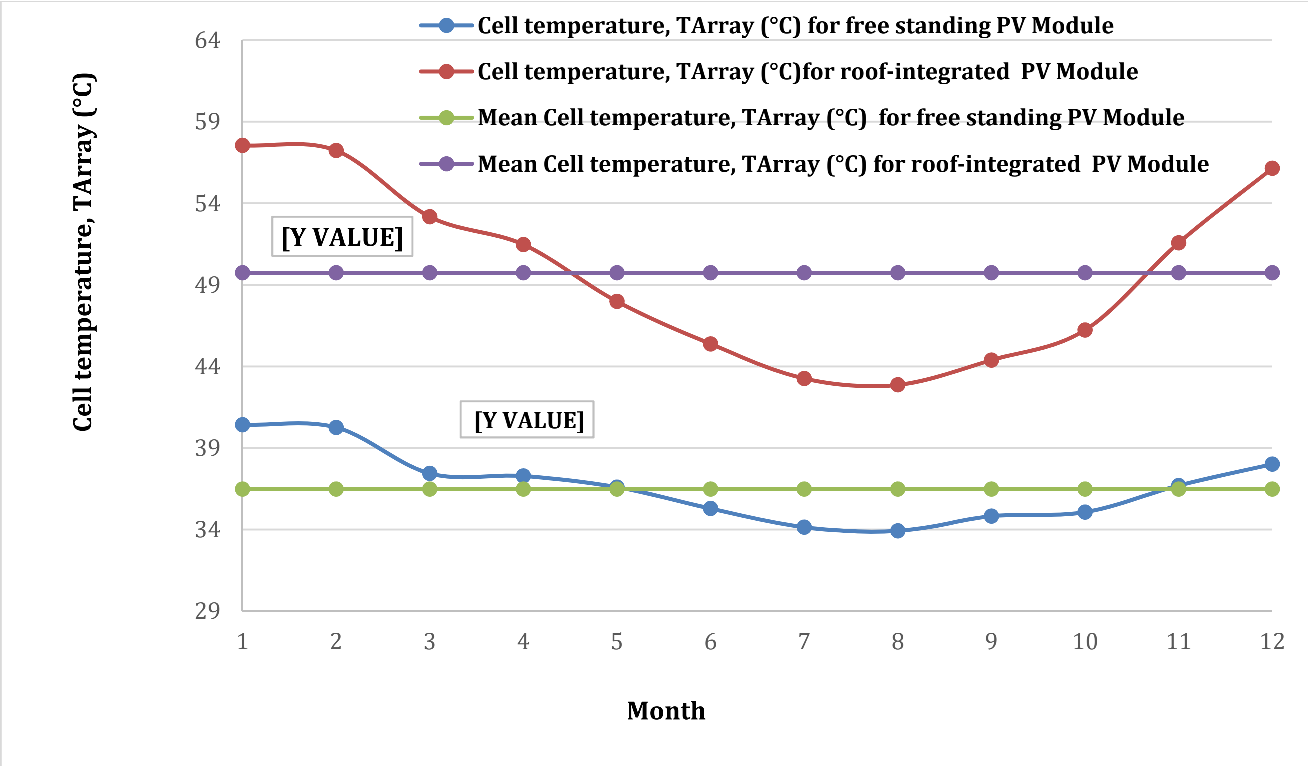


Figure 14 The scatter plot of the **cell temperature, TArray (°C)**

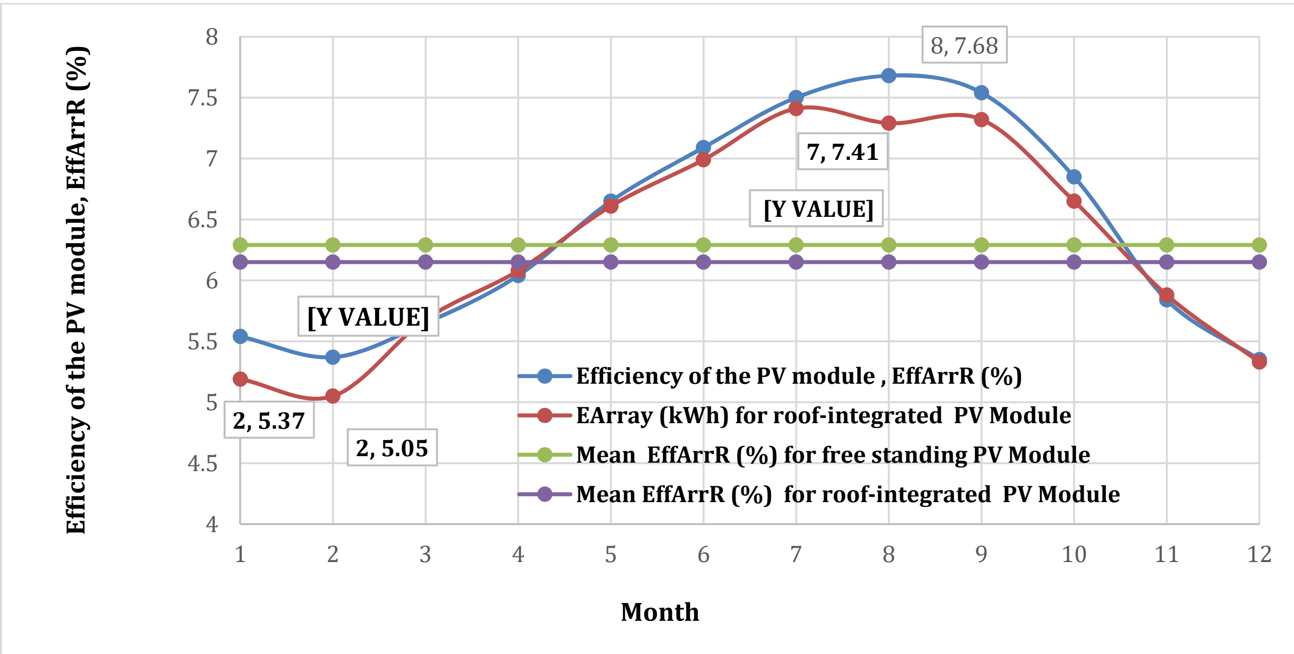


Figure 15 The scatter plot of the **efficiency of the PV module, EffArrR (%)**

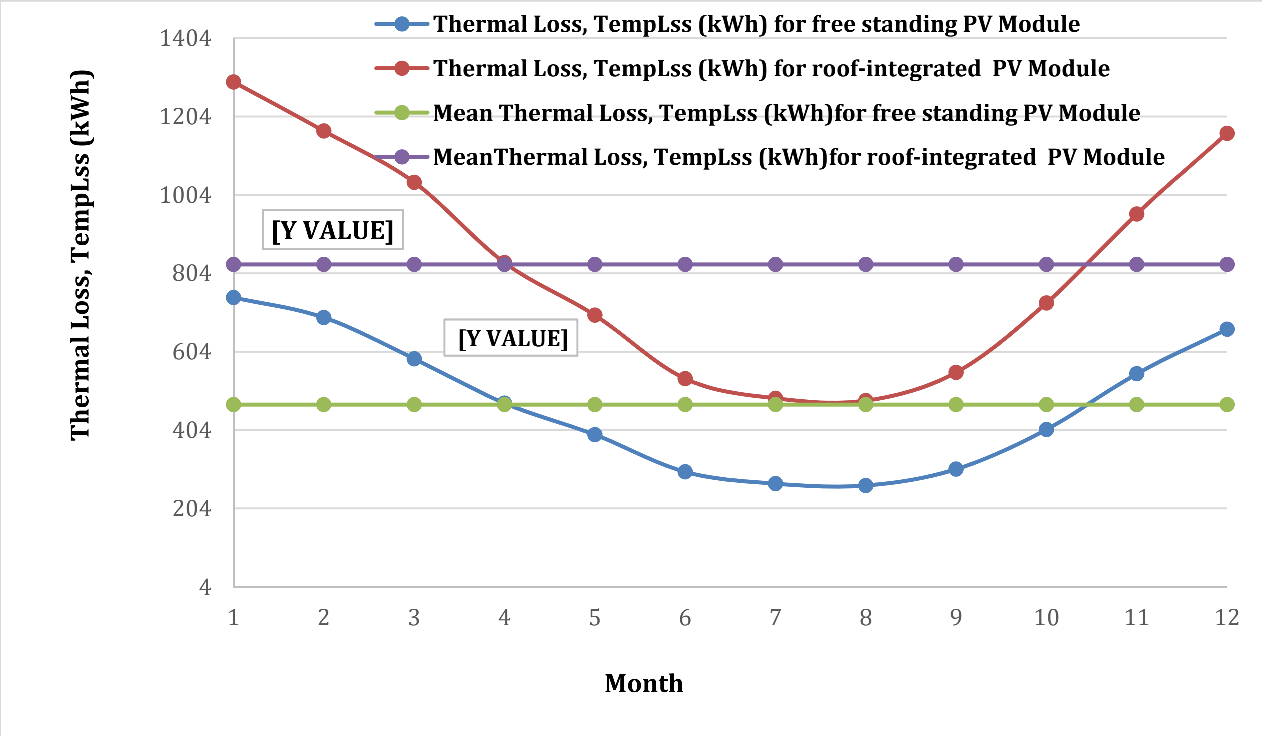


Figure 16 The scatter plot of the thermal Loss, TempLss (kWh)

4. CONCLUSION

The study examined the effect of the PV array mounting style on the performance of standalone PV power system used to power an automated teller machine. The study considered two different PV module mounting styles, namely; the free standing PV (FSPV) module with adequate air circulation and the roof integrated PV (RIPV) module with in adequate air circulation. The study was conducted with PVSyst as the simulation software which is used to size the PV power system components and also to evaluate the performance of the system under the two PV module mounting styles.

The results show that the cell temperature of the RIPV mounted system has higher cell temperature,, lower cell efficiency , higher thermal loss, lower PV array energy yield and lower solar fraction when compared with the FSPV mounted system. In all, the results show that the FSPV mounting gives better performance than the RIPV mounting approach.

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