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Simulated Analysis Of Net Zero Photovoltaic Power Installation For Microfinance Bank

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***Abstract*— In this paper, simulated analysis of net zero photovoltaic power installation for microfinance banks is presented. The case study microfinance bank is located at latitude of 5.032867 and longitude of 7.911871 and it has daily electric energy demand of 62,792 kWh/day which amounts to 22919.08 KWh/year. The photovoltaic (PV) system component sizing was done with PVSyst simulation software. The result showed that there is a total of 13932 kWh imported energy from the grid per annum and 13932 kWh exported energy to the grid per annum. Essentially, there is a net surplus energy of 1 kWh per annum, which amounts to about 0.002739726 kWh/day $\approx 0 \mathrm{kWh/day}$. Approximately, there is a net zero daily energy import and export. In all, from the results it can be concluded that the PV system for the microfinance bank is generating sufficient energy annually for the required electric energy demand which is confirmed by a result of annual solar fraction of 1.0.**

***Keywords*—** Net-Zero Energy, Photovoltaic, Energy Demand, PVSyst Simulation Software , Microfinance Bank, Solar Fraction

1. INTRODUCTION

Over the years, microfinance banking has been found to be among the main drivers of financial inclusion [12,3,4,5,6,7,8,9,10,11]. Particularly, microfinance banks provide financial support to the small and medium scale enterprises, as well as to the real sector of the economy [12, 13, 14, 15, 16, 17]. In this way, microfinance banks play critical roles that can fast track economic growth in the developing countries, such as Nigeria.

In other to function effectively, the microfinance banks rely on the contemporary information and communication technologies [18, 19, 20, 21, 22, 23, 24]. Among other things, steady electric power supply and internet access are required. However, in developing countries like Nigeria, access to steady power supply is very limited [25, 26, 27, 28, 29, 30]. As such, many of the microfinance banks rely on alternative power sources, such as fossil fuel-based electric generators and photovoltaic (PV) solar power systems [31,32,33,34,35].

In this paper, analysis of a net zero PV solar power supply system for a microfinance bank is presented. Basically, net zero PV power supply system is designed such that over a given period, which in this paper is a year, the total energy generated by the PV power system is just sufficient to meet the electric energy demand of the load within the given period [36,37,38,39,40]. Also, net zero PV power system is usually a grid-connected system in which excess energy generated by the PV power system at any point in time is exported to the grid while any energy shortfall in the required load demand at any time is imported from the grid. In all, over the given period of one year, the total energy imported from the grid is equal to the total energy exported to the grid. This gives a net zero energy to the grid and from the grid.

The performance evaluation is implemented using PVSyst software along with the daily load demand data for the case study microfinance bank and the meteorological data of the microfinance bank location. The details of the relevant mathematical expressions and simulation datasets are presented.

2 METHODOLOGY

Net zero energy PV solar power system is a grid connected system that is designed such that the total annual energy exported to the grid (E_{YEXP}) is equal to the total energy imported from the grid (E_{YIMP}). In that case, for a period of one year, the net annual energy (E_{NET}) is zero. Now, for a given daily energy demand, $\mathrm{E_{DL}}$, the annual energy demand ($\mathrm{E_{AN}}$) is determined as follows;

$$\mathrm{E_{AN}} = 365 * \mathrm{E_{DL}} \quad (1)$$

Let PSH be the peak sun hour at the installation site, P_{Wp} denote the PV array rated watt peak power, N_{PV} denote the number of PV panels that makeup the array and f_{PV_derat} denote the PV array de-rating factor, then the daily energy yield of the array is given as;

$$\mathrm{E_{DL}} = (N_{PV})(P_{Wp})(PSH)(f_{PV\_derat}) \quad (2)$$

Hence;

$$\mathrm{E_{AN}} = 365 * [(N_{PV})(P_{Wp})(PSH)(f_{PV\_derat})] \quad (3)$$

In the computation of $\mathrm{E_{DL}}$, the annual average value of PSH or a given single average value of PSH is assumed. However, since the instantaneous value of PSH varies over the day and year, the value of $\mathrm{E_{DL}}$ also varies all through the day and year.

Hence, at any instant of time or on any given day, the energy yield may exceed the required load demand. In that case, the excess energy is exported to the grid, where the total annual energy exported to the grid in a year is denoted as E_{YEXP}. On the other hand, the energy yield may be less than the required load demand. In this cases, the deficit energy is imported from the grid, where the total annual energy imported from the grid in a year is denoted as E_{YIMP}. Then, the annual net energy, denoted as E_{NET} is given as;

$$E_{NET} = E_{YEXP} - E_{YIMP} \quad (4)$$

Now, let $\mathrm{PSH}_{(n)}$ be the value of PSH on day n and let $\mathrm{E_{DL(n)}}$ be the value of $\mathrm{E_{DL}}$ on day n, $E_{YIMP(n)}$ be the value of E_{YIMP} on day n, $E_{YEXP(n)}$ be the value of E_{YEXP} on day n and $E_{NET(n)}$ be the value of E_{NET} on day n, where n =1,2,3,…,365, then,

$$\mathrm{E_{DL(n)}} = (N_{PV})(P_{Wp})(\mathrm{PSH}_{(n)})(f_{PV\_derat}) \quad (5)$$

Also, the daily consumed energy, denoted as E_{SELF} is equal to $\mathrm{E_{DL}}$, that is;

$$E_{SELF} = \mathrm{E_{DL}} \quad (6)$$

Now,

$$\mathrm{E_{DL(n)}} - \mathrm{E_{DL}} = \mathrm{E_{DL(n)}} - E_{SELF} \quad (7)$$

where PSH is the annual average peak sun hour. Hence;

$$E_{YEXP(n)} = \max(0, \mathrm{E_{DL(n)}} - E_{SELF}) \quad (8)$$

$$E_{YEXP(n)} = \max\left(0, (N_{PV})(P_{Wp})(\mathrm{PSH}_{(n)} - PSH)(f_{PV\_derat})\right) \quad (9)$$

$$E_{YIMP(n)} = \max(0, \mathrm{E_{DL(n)}} - E_{SELF}) \quad (10)$$

$$E_{YIMP(n)} = \min\left(0, (N_{PV})(P_{Wp})(\mathrm{PSH}_{(n)} - PSH)(f_{PV\_derat})\right) \quad (11)$$

$$E_{NET(n)} = E_{YEXP(n)} + E_{YIMP(n)} \quad (12)$$

Notably, $E_{YEXP(n)}$ is positive or zero whereas $E_{YIMP(n)}$ is negative or zero. Over the year of 365 days, the overall net annual energy, E_{NET} is given as;

$$E_{NET} = \sum_{n=1}^{365}\{E_{YEXP(n)} + E_{YIMP(n)}\} \quad (13)$$

The self-consumed energy over the year, is denoted as E_{SELFYR} and it is given as;

$$E_{SELFYR} = \sum_{n=1}^{365}\{\mathrm{E_{DL}}\} = \sum_{n=1}^{365}\{E_{SELF}\} \quad (14)$$

$$E_{SELFYR} = \sum_{n=1}^{365}\{\mathrm{E_{DL}}\} = \sum_{n=1}^{365}\{E_{SELF}\} \quad (15)$$

$$E_{SELFYR} = \mathrm{E_{AN}} = 365 * [(N_{PV})(P_{Wp})(PSH)(f_{PV\_derat})] \quad (16)$$

2.2 The load demand profile and solar radiation data for the case study microfinance bank

The case study microfinance bank is located at latitude of 5.032867 and longitude of 7.911871, as shown in Figure 1. The load demand profile for the case study microfinance bank is given in Table 1 while the solar radiation data is presented in Table 2 and Figure 2 and Figure 3. The daily average global solar radiation on the horizontal plane (GlobHor) and annual average of daily global solar radiation on the horizontal plane for the case study microfinance bank are presented in Figure 3. Also, the monthly average global solar radiation on the horizontal plane (GlobHor) for the case study microfinance bank is presented in Table 3.

Table 1 The Case Study Microfinance Bank Load Profile

S/N	Description of Item	Qty	Power (Watts)	Total load (Watts)	Daily Hour of Actual Utilization (hours)	Daily (Wh)
1	ATM Machine	4	1000	4000	14	56000
2	Premises/Street Lightings	8	40	320	14	4480
3	Wireless Access Point	2	12	24	24	576
4	Laptop (with security cable)	2	40	80	14	1120
5	HP Deskjet (three-in-one) printer/scanner and photocopier	1	44	44	14	616
	Daily Total			4468		62792
	Annual Total	365 *62792 =				22919.08 KWh/year

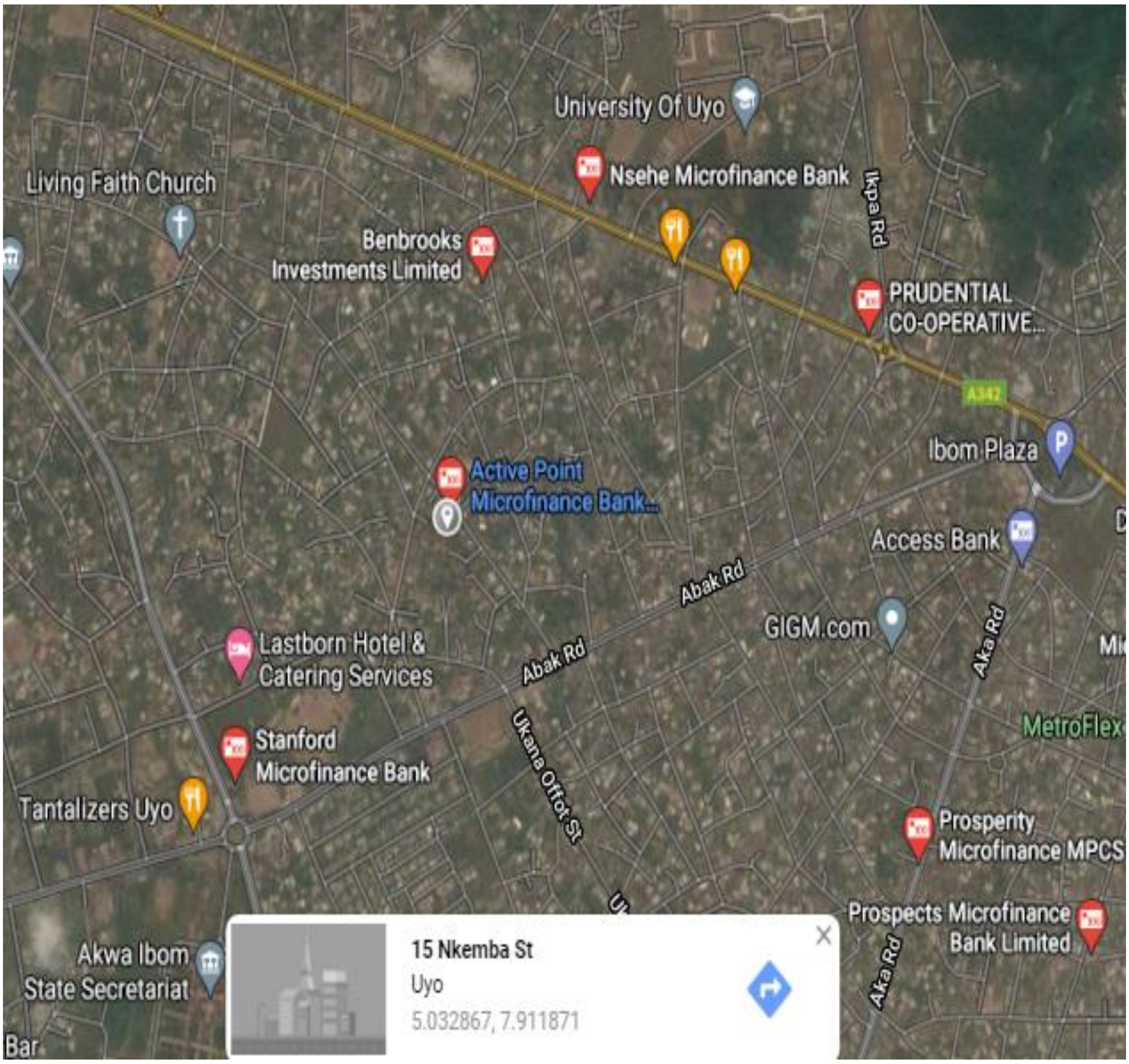

Figure 1 **The Location of the Case Study Microfinance Bank**

Figure 1 Monthly solar radiation data for the **Case Study Microfinance Bank**

Table 2 The monthly average global solar radiation on the horizontal plane (GlobHor) for the Case Study Microfinance Bank

Month	Monthly GlobHor kWh/m².mth
Jan	165.2
Feb	149.2
Mar	160.9
Apr	151.5
May	141.1
Jun	112.5
Jul	102.3
Aug	117.8
Sep	109.5
Oct	132.1
Nov	149.1
Dec	159
Year	1650.2

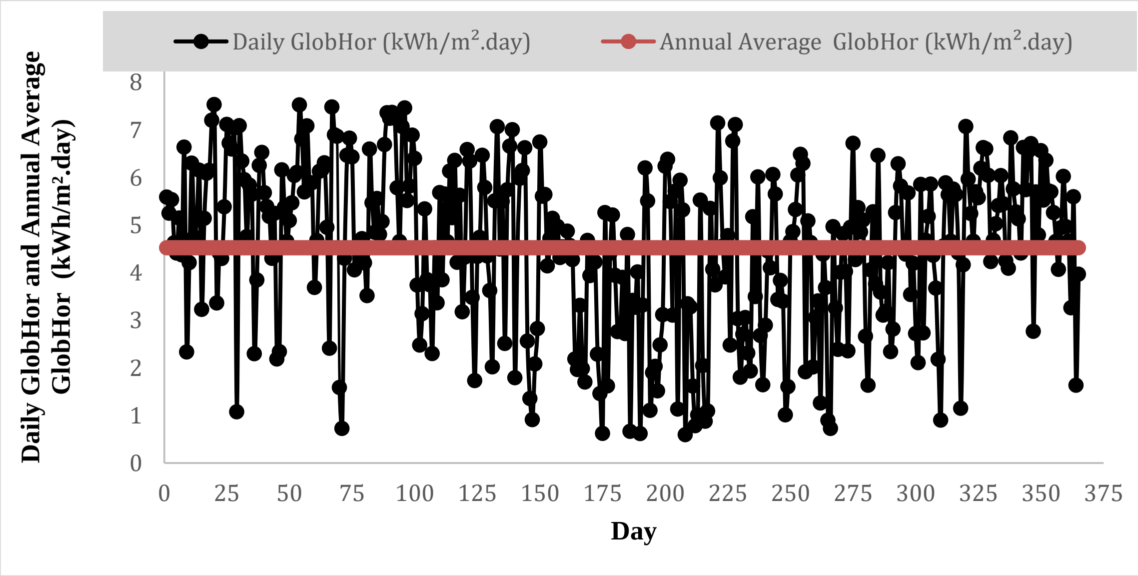

Figure 2 Plot of the daily average global solar radiation on the horizontal plane (GlobHor) and annual average of daily global solar radiation on the horizontal plane for the Case Study Microfinance Bank

3. RESULTS AND DISCUSSION

The sizing of the PV system for the microfinance bank was conducted using PVSyst simulation software with daily energy demand of 62,792 kWh/day which amounts to 22919.08 KWh/year. The PV modules and inverter selected using the PVSyst software are presented in Figure 3. The results of the monthly and annual energy use and users energy need are presented in Table 4. The bar chart of the monthly available energy at the output of the PV array, E Avail (kWh) and the monthly energy demand of the user load, E Load (kWh) is shown in Figure 4. Furthermore, the loss diagram showing the annual energy imported from the grid and the annual energy exported to the grid is given in Figure 5. The result in Figure 5 showed that there is a total of 13932 kWh imported energy from the grid per annum and 13932 kWh exported energy to the grid per annum. Also, Figure 6 shows the bar chart of the daily available energy at the output of the PV array, daily imported energy, daily exported energy and daily self-consumed energy. From the results in Figure 5, there is a net surplus energy of 1 kWh per annum, which amounts to about 0.002739726 kWh/day $\approx$ 0kWh/day . Approximately, there is a net zero daily energy import and export. In essence, the PV system for the microfinance bank is generating sufficient energy annually for the required electric energy demand which is confirmed by the result in Table 4 that shows annual solar fraction of 1.0.

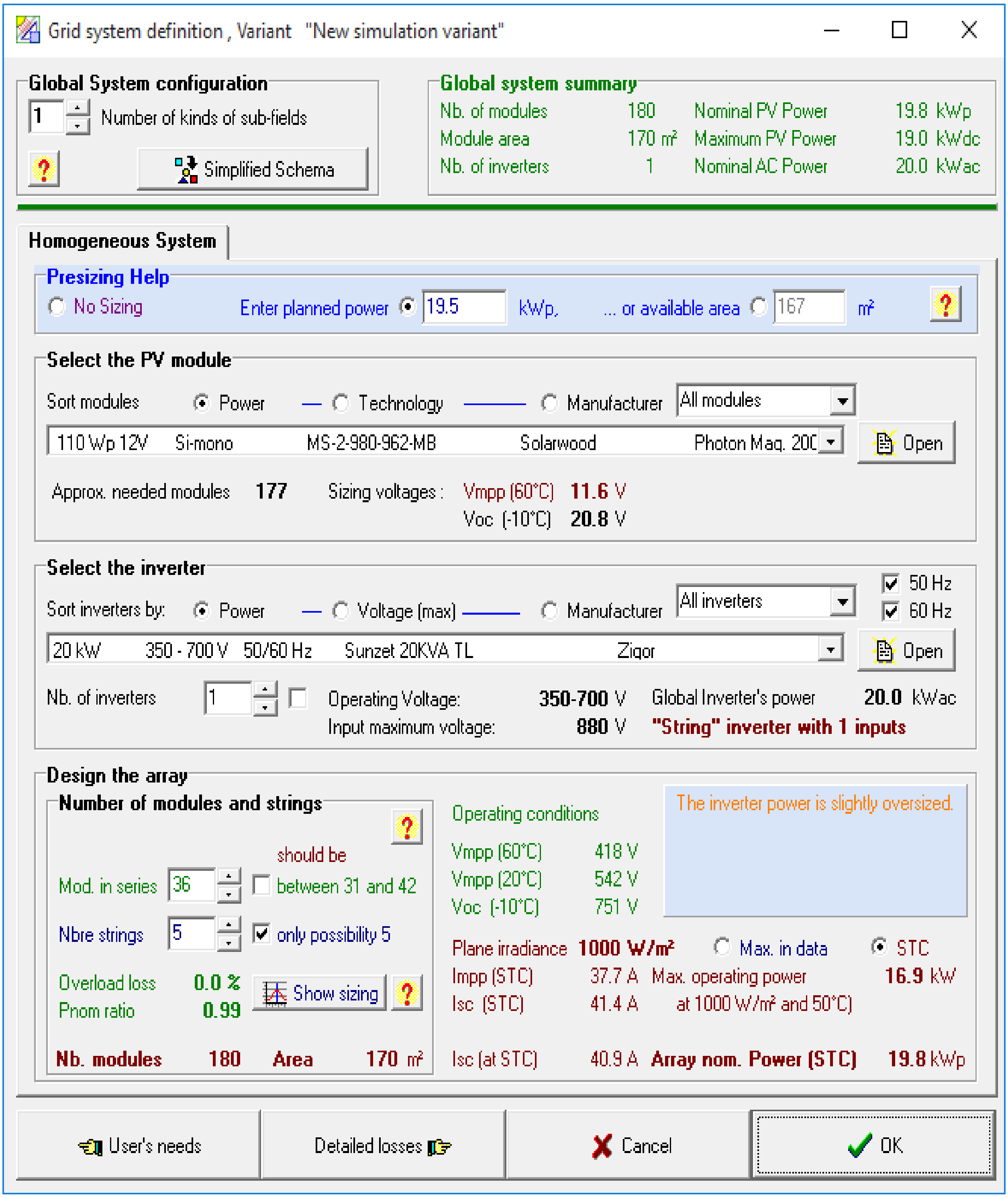

Figure 3 The PVSyst dialogue box showing the selected PV modules and inverter

Table 3. The monthly and annual energy use and users energy need

Month	Available Energy at the output of the PV Array, E Avail (kWh)	Energy demand of the load, E Load (kWh)	Energy supplied to the user, E User (kWh)	Energy injected into the grid, E Grid (kWh)	The fraction of the user energy demand that is supplied from the PV array, SolFrac
January	2379	1979	839.3	1540	1.20
February	2093	1788	759.6	1334	1.17
March	2246	1979	827	1419	1.14
April	2091	1917	813.4	1277	1.09
May	1907	1979	788.1	1119	0.96
June	1566	1924	757.2	809	0.82
July	1407	1979	702.7	705	0.71
August	1650	1979	760.2	890	0.83
September	1563	1925	715.1	847	0.82
October	1917	1979	809.1	1108	0.97
November	2166	1925	788.7	1377	1.13
December	2345	1979	837.6	1508	1.19
Year	23330	23332	9398	13933	1.00

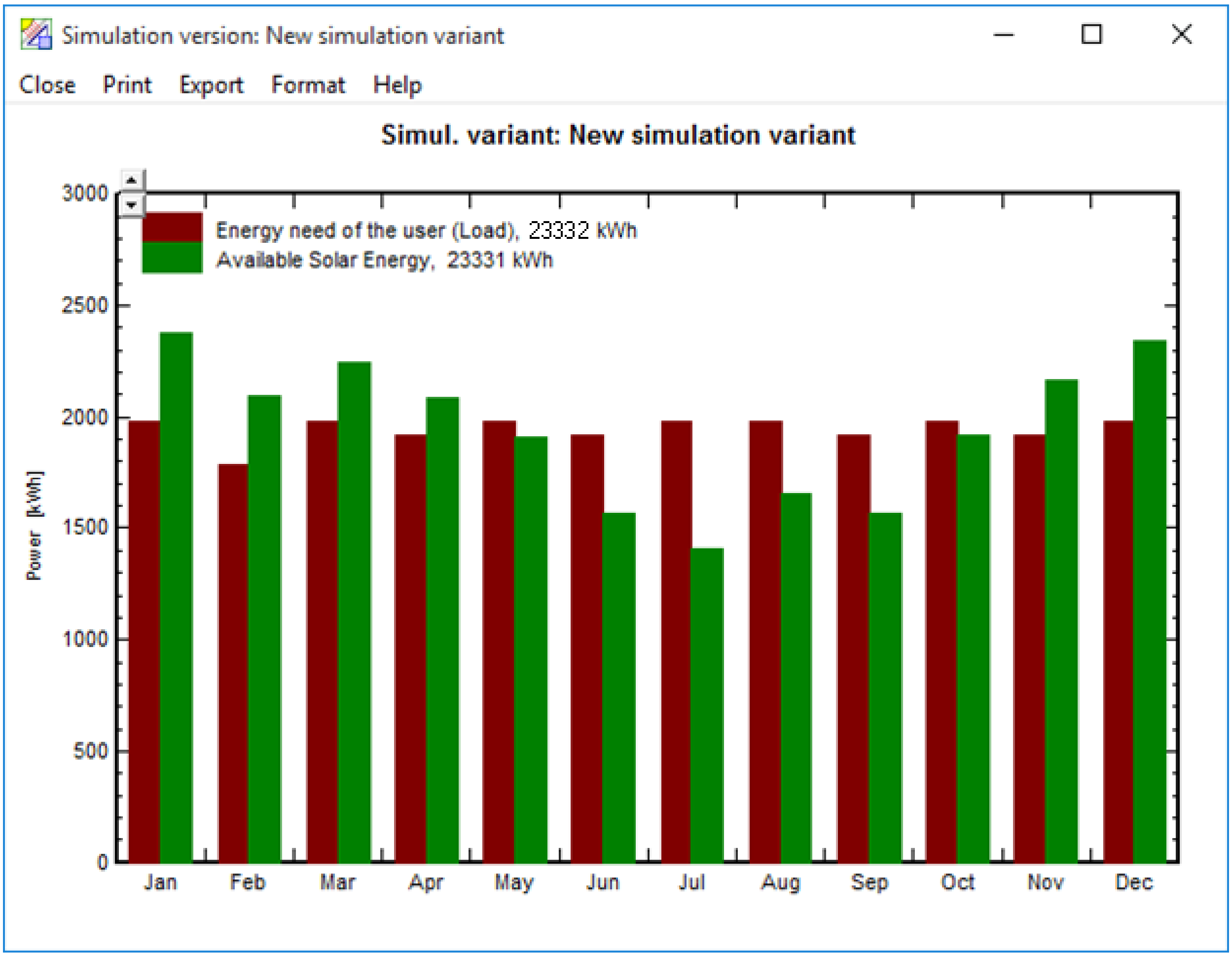

Figure 4 The bar chart of the monthly available energy at the output of the PV array, E Avail (kWh) and the monthly energy demand of the load, E Load (kWh)

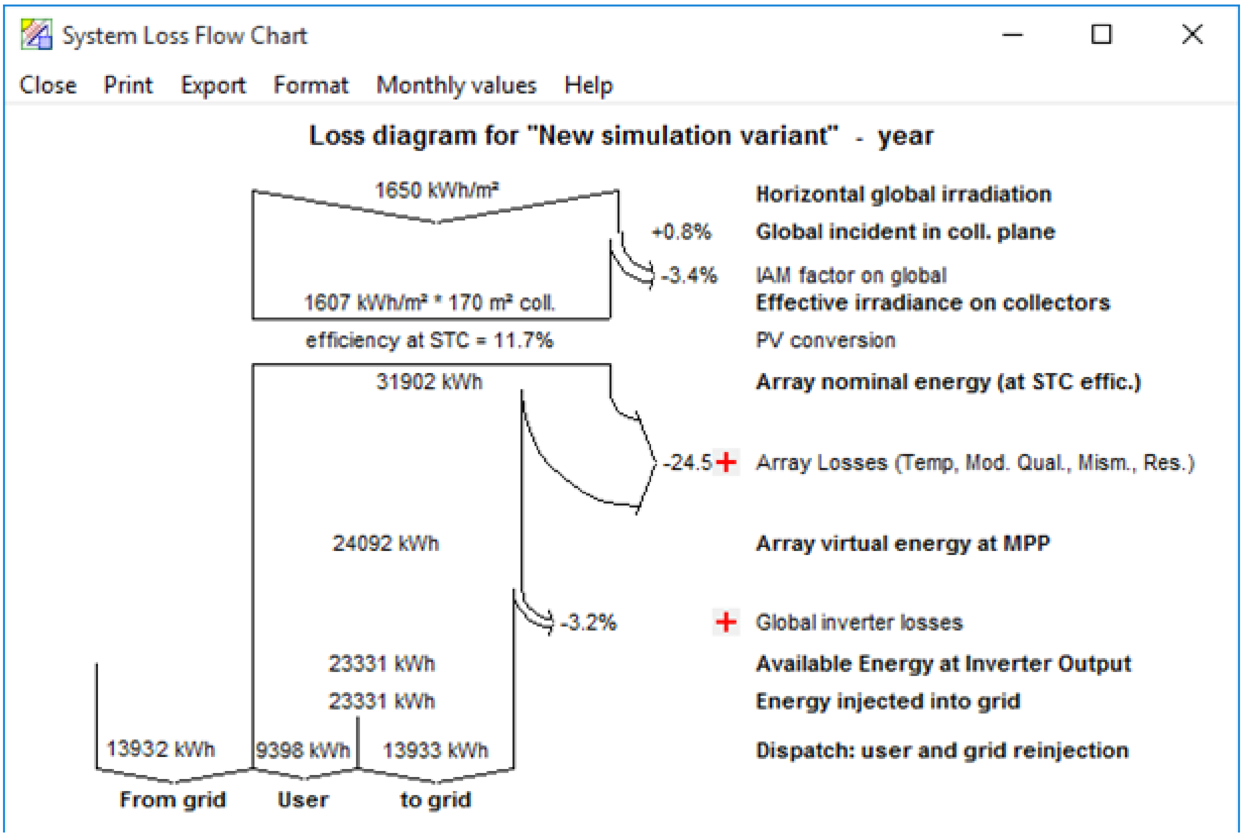

Figure 5 The loss diagram showing the annual energy imported from the grid and the annual energy exported to the grid

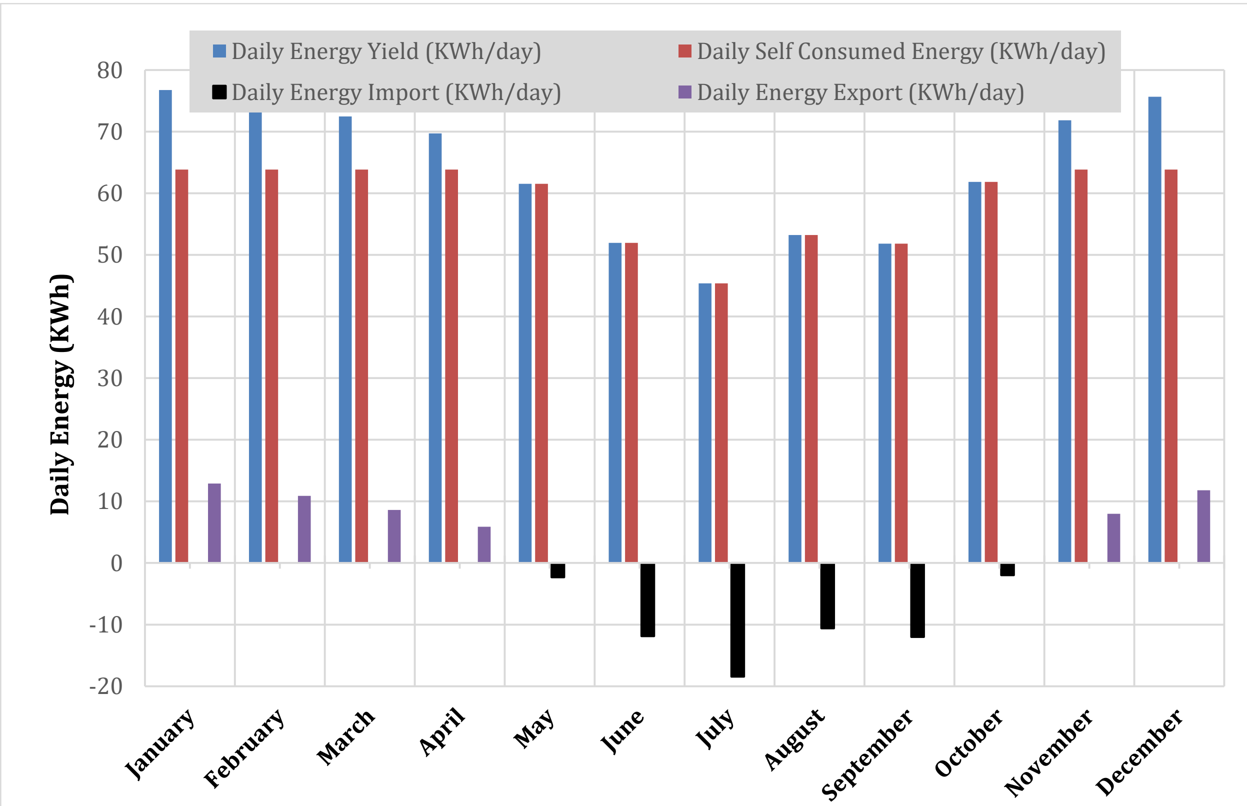

Figure 6 The bar chart of the daily available energy at the output of the PV array, daily imported energy, daily exported energy and daily self-consumed energy.

4. CONCLUSION

Sizing of a PV power system for a net zero energy supply for a microfinance bank is presented. The PV component sizing was done using PVSyst simulation software. The daily peak sun hour of the case study site and daily energy demand of the case study microfinance bank were obtained and used to select the PV modules and inverter size that satisfied the net zero energy system. The results indicated that the PV system for the microfinance bank is generating sufficient energy annually for the required electric energy demand which is confirmed by the result of annual solar fraction of 1.0.

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