Analysis of a grid-connected rooftop solar power for supermarket in Uyo

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***Abstract*—Analysis of a grid-connected rooftop solar power for supermarket in Uyo, AkwaIbom State is presented. The supermarket has a total daily energy demand of 49,900.0 Wh per day with an annual average Peak Sun Hour of 4.8 hours/day. The effective available roof area for mounting solar panels is determined as 785 m^2. The PVSyst software is used to carry out the sizing operation. The results show that the system normalized yearly energy production is 124 Mwh/year, the specific energy production is 1263 Kwh /Kwp/yr and the system performance ratio is 0.728 (or 72.8%). The annual average solar fraction of the solar power system is 0.283. This means that the solar power supply only about 28.3 % of the annual energy demand of the user. The lowest solar fraction of 0.22 occurred in July and August while the highest solar fraction of 0.347 occurred in January. With respect to the total energy produced, about 21.6% is lost to the array due to array cell temperature, dust, module efficiency and other array de-rating factors. Also about 5.6% of the energy is lost to other system components. In all, only about 72.8 % are useful energy while a total of about 27.2 % are lost.**

Keywords—Rooftop Solar Power, Renewable Energy, Grid-Connected Solar Power, Cell Temperature, Performance Ratio, Solar Fraction, Standalone Solar Power

I. Introduction

Many supermarkets across Nigeria rely heavily on the national grid and diesel generators for their daily energy supply due to the poor and epileptic power supply from the national grid [1,2,3,4,5,6,7,8]. As the quest for clean energy rises, the use of diesel generators is discouraged [9,10,11,12,13,14]. However, solar photovoltaic (PV) power system has high initial investment cost [15,16,17,18,19]. In any case, most business outfit owners are willing to setup solar power, especially when it has been proven in several life cycle cost analysis studies that the solar power system is viable with good payback period [20,21,22,23,24]. Also, advancements in solar PV technologies are leading to continuous drop in PV cost and also subsidies provided by government are making the solar power more affordable for users [25,26,27,28,29].

In any case, users of PV power in the city are faced with the problem of availability of space for the PV array. As such, most PV power system installation with the city centers are rooftop PV, whereby the PV panels are mounted on the rooftop [30,31,32]. Accordingly, in this paper, a grid-connected PV power system for a supermarket in the busy area of Uyo metropolis is presented. The PV is power is meant to supply the shortfalls in the grid power supply to the supermarket. As such, the available rooftop area in the supermarket is assessed and the PV array that will fit into the available rooftop area is used to generated additional power which will make up for the annual average missing power of 30% from the national grid. The sizing of the grid-connected solar power system is carried out using PVSyst software [33] and the relevant system parameters are used to assess the performance of the power system

II. Methodology

The total usable roof area (A_{pv}) for PV module installation is 55 m^2. The sizing of the PV system can be done in two ways; one , based on the daily power demand and two, based on the available area for the PV modules. For any given daily load demand (E_L) $in\ Kwh/day$ with de-rating factors $f_{dc/ac}$ and $\mathrm{f_{temp}}$, the PV size in terms of area (A_{pv}) required to meet the daily load demand is given as [34,35,36, 37]

$$A_{pv} = \frac{E_L}{(G_d * \eta_{pv} * f_{dc/ac} * \mathrm{f_{temp}})} \qquad (1)$$

Conversely, for any given PV size in terms of area, A_{pv}, the

The daily load (E_{PV}) $in\ Kwh/day$ that can be generated with the PV of area A_{pv} in $\mathrm{m}^2$is given as;

$$E_{PV} = A_{pv}\,(G_d * \eta_{pv} * f_{de-rating}) \qquad (2)$$

Where G_d is the average daily Peak Sun Hour (PSH) ,η_{pv} is the efficiency of the PV module and $f_{de-rating}$ includes all the de-rating factors normally considered in PV system design and a typical value is 0.8.

The daily load demand of the supermarket is given in Table 1. A total power of 4,575.0 watts is needed with corresponding total daily energy demand of 49,900.0 Wh per day. The energy demand is modeled in PVSyst as yearly constant daily energy demand of 49.9 Kwh/day. The daily Peak Sun Hour (PSH) of the study site is given in Figure 1. The analysis is carried out with the yearly average PSH for the tilted plane which in Figure 1 is given as 4.8 hours/day.

Table 1 The daily load demand of the supermarket

Electric Appliance	Wattage (W)	Qty.	Total Wattage	Hours of operation per day	Daily energy demand (kWh)
Refrigeration	200.0	3	600	12	7,200.0
Air condition	1,000.0	2	2000	12	24,000.0
Computer	120.0	1	120	12	1,440.0
Printer	120.0	1	120	12	1,440.0
Television	75.0	1	75	12	900.0
Fans	60.0	6	360	12	4,320.0
Lighting	20.0	15	300	12	3,600.0
Other Miscellaneous	500.0	1	500	12	6,000.0
Power for testing Electronic products	500.0	1	500	2	1,000.0
Total			**4,575.0**		**49,900.0**

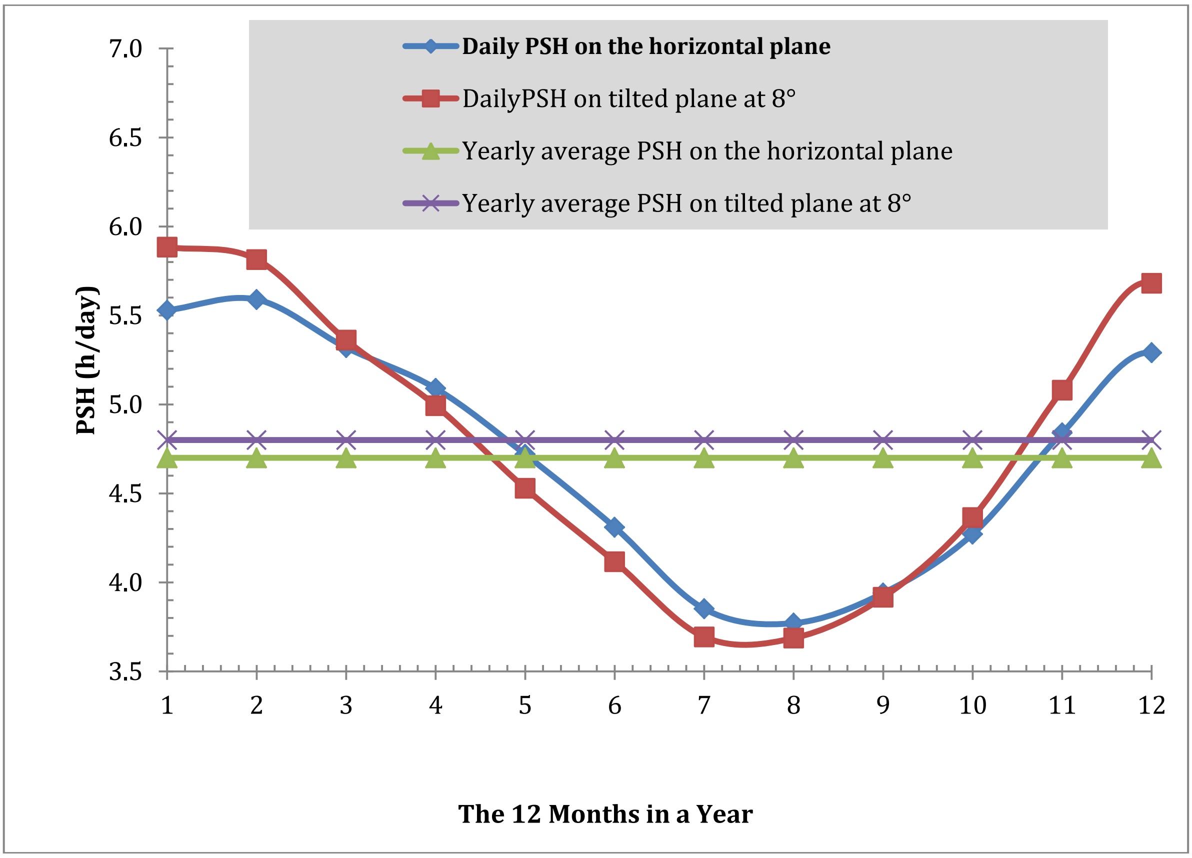

Figure 1 : The daily Peak Sun Hour(PSH) of the study site

III. Results and discussion

The schematic diagram of the grid-connected rooftop solar power system is given in Figure 2. Based on the daily load demand, the PVSyst is used to select the PV array and the inverter for the solar power system, as shown in Figure 3. The main system result in Figure 4 shows that the system normalized yearly energy production is 124 Mwh/year, the specific energy production is 1263 Kwh /Kwp/yr and the system performance ratio is 0.728 (or 72.8%) . Also, the yearly normalized energy production is 3.46Kwh/kWp/day with normalized system loss of 0.27 Kwh /Kwp/day and normalized array loss of 1.03 Kwh /Kwp/day.

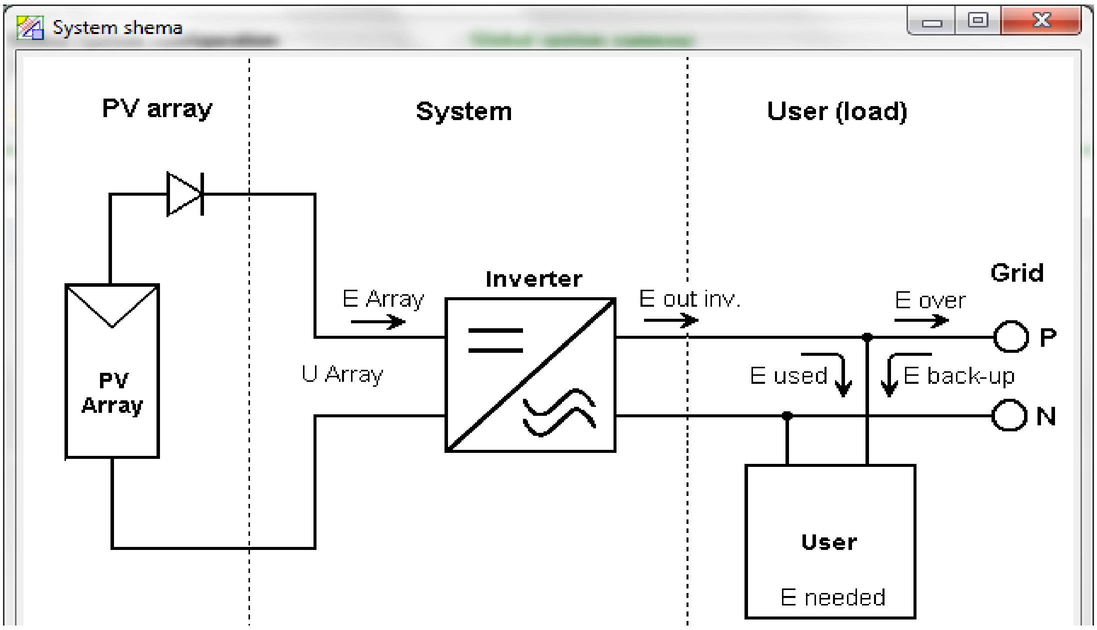

Figure 2 Schematic diagram of the grid connected solar power system

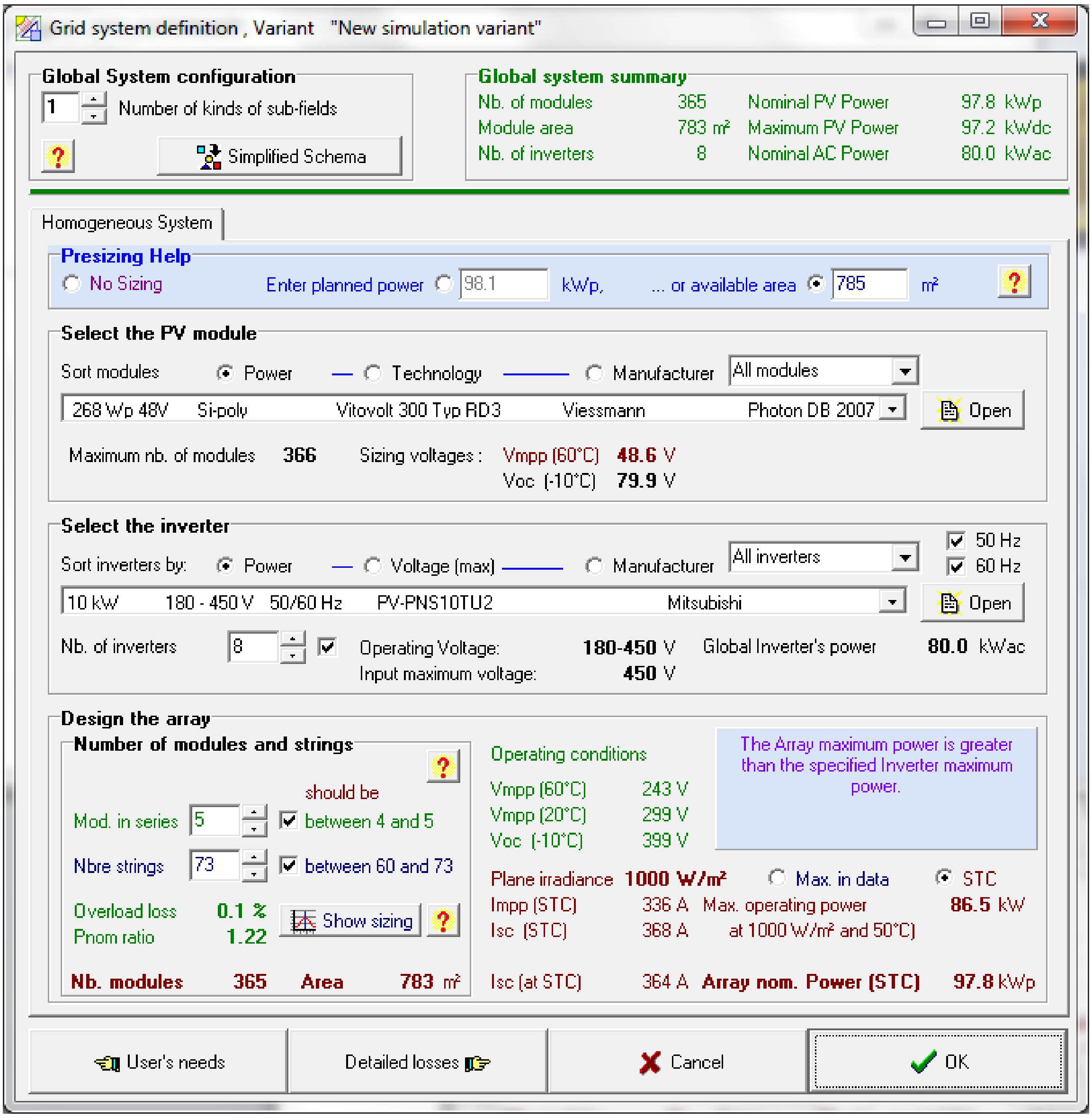

Figure 3 The selected PV module and inverter for the solar power system

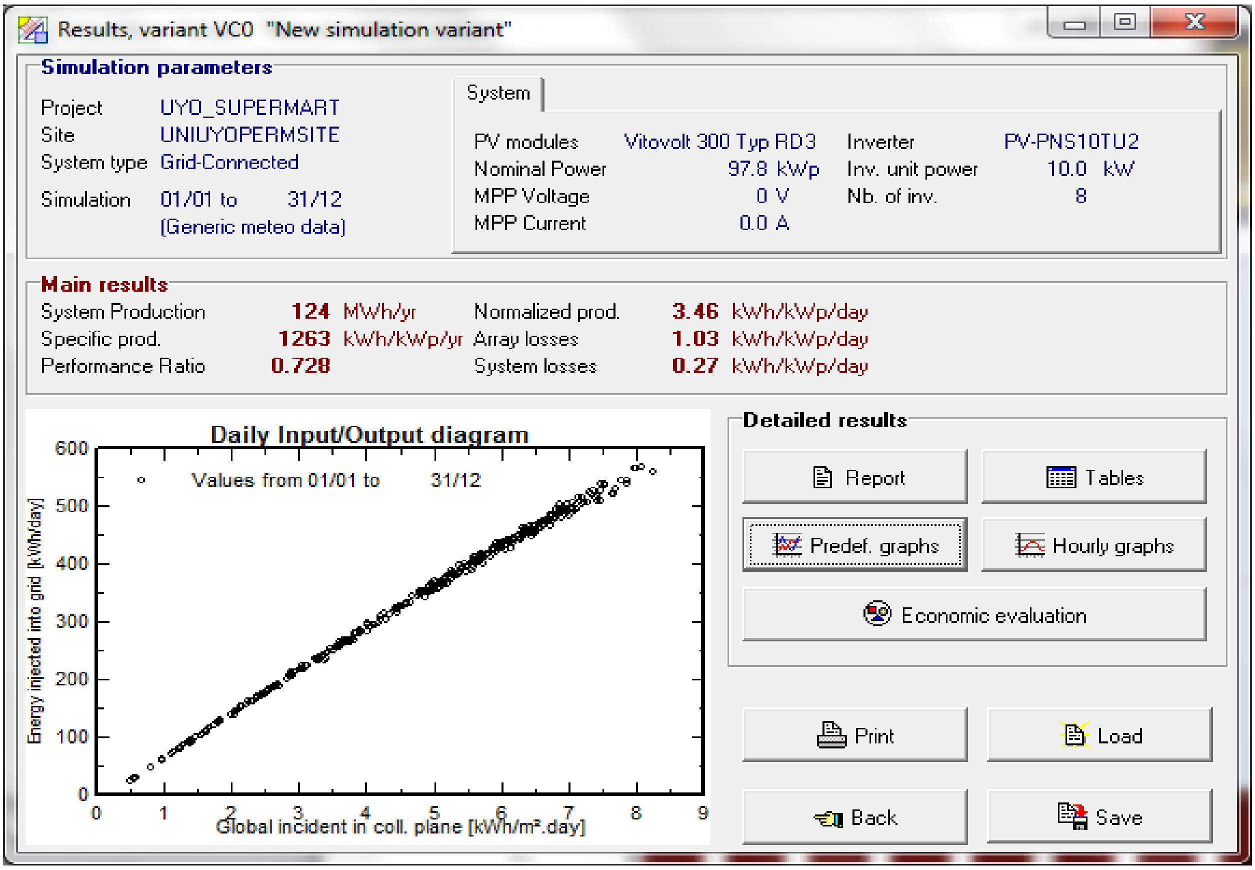

Figure 4 The main system energy production result

New simulation variant

Energy use and User's needs

	E Avail kWh	E Load kWh	E User kWh	E GridI kWh	SolFrac
January	12897	37126	11466	1431	0.347
February	11468	33533	10498	970	0.342
March	11838	37126	10793	1045	0.319
April	10687	35928	9934	753	0.297
May	10030	37126	9563	468	0.270
June	8834	35928	8684	149	0.246
July	8162	37126	7946	216	0.220
August	8181	37126	7910	270	0.220
September	8382	35928	8021	361	0.233
October	9694	37126	9175	519	0.261
November	10864	35928	10219	645	0.302
December	12503	37126	11066	1438	0.337
Year	123542	437124	115276	8266	0.283

Figure 5: Energy use and user's needs

The annual average solar fraction of the solar power system is 0.283. This means that the solar power supply only about 28.3 % of the annual energy demand of the user. The lowest solar fraction of 0.22 occurred in July and August while the highest solar fraction of 0.347 occurred in January. The loss diagram for the grid-connected solar power is given in Figure 6. With respect to the array nominal energy production, about 10.4 % of the energy is lost due to array cell temperature. Another major loss is the inverter loss which is about 7.1%. The normalized production and loss factor bar chart is shown in Figure 7. According to Figure 7, with respect to the total energy produced, about 21.6% is lost to the array due to array cell temperature, dust, module efficiency and other array de-rating factors. Also about 5.6% of the energy is lost to other system components. In all, only about 72.8 % are useful energy while a total of about 27.2 % are lost.

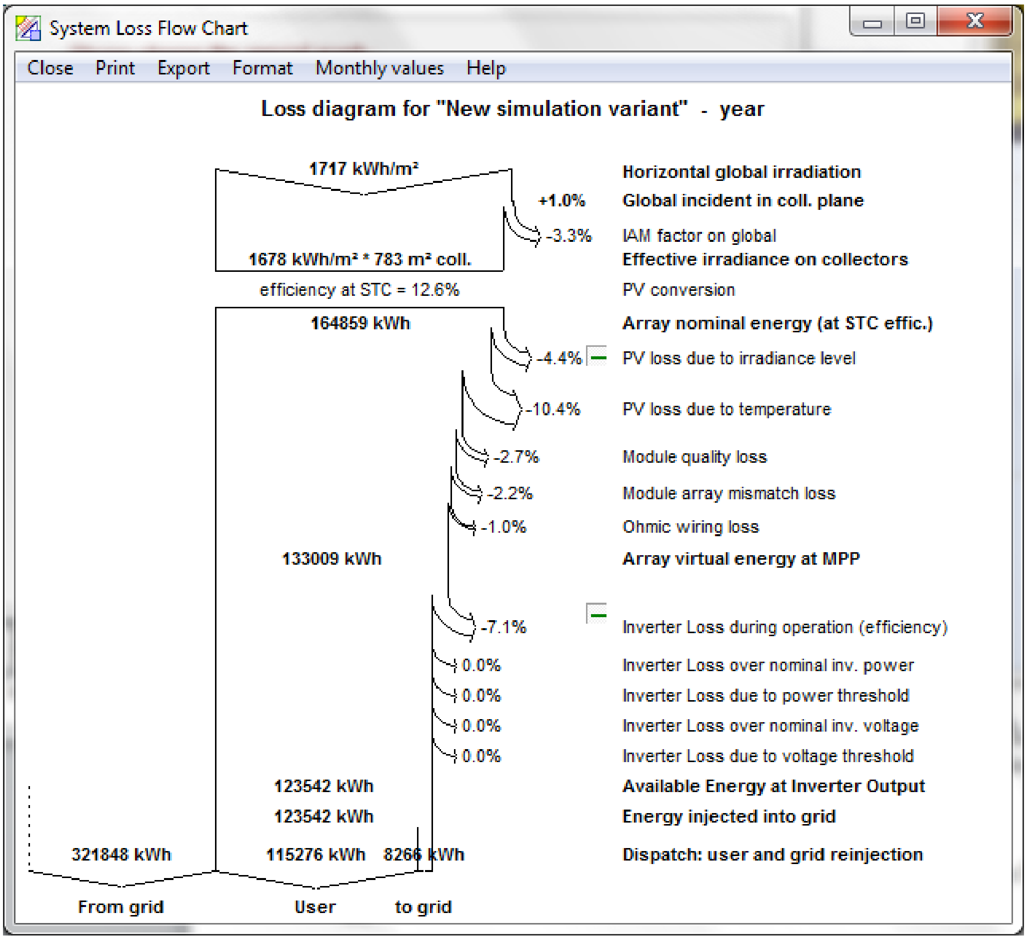

Figure 6 The loss diagram

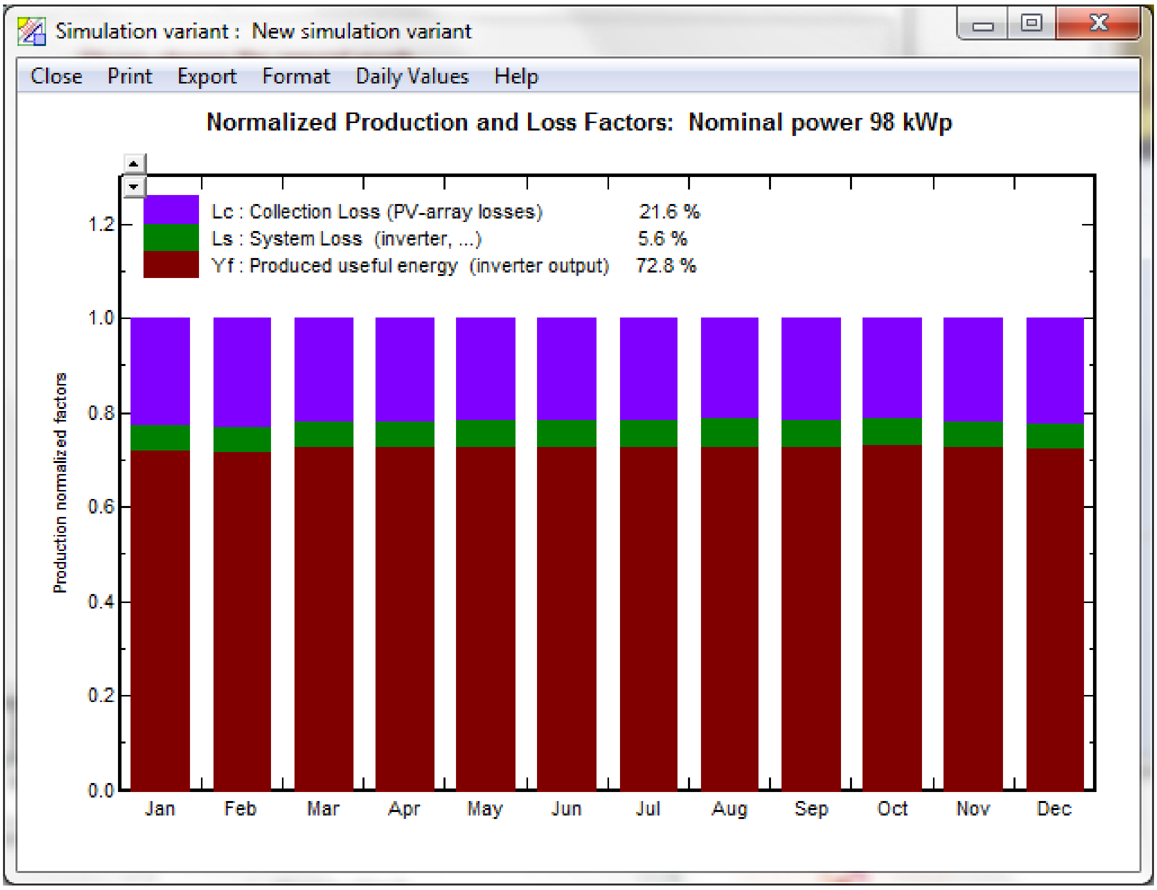

Figure 7 The bar chart of normalized production and loss factor

IV Conclusions

The sizing of a grid-connected rooftop solar power system for a supermarket is presented. The effective available roof area for mounting solar panels is determined along with the daily energy demand of the supermarket. The PVSyst software is used to carry out the sizing operation. Key system performance parameters are identified and used to assess the system. In all, the rooftop solar power is able to provide about 28% of the annual energy demand of the supermarket. The rest of the energy is supplied from the national grid.

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