Evaluation Of Off-Grid Solar Power System For Remote Self-Service Banking Kiosk In Cross River State

Akpan, Akaninyene Ndarake[1]
Department of Electrical/Electronic Engineering
Cross River State University of Technology (CRUTECH)
candyguy23@gmail.com

Nwaibe obiora Chukwuma[2]
Advanced Space Technology Applications Laboratory Uyo,
National Space Research and Development Agency,
Federal Capital Territory, Abuja, Nigeria

Lehiowo Obojor-Ogar[3]
Department of Electrical/Electronic Engineering
University of Calabar, Cross River State , Nigeria
lehiobojor@unical.edu.ng

Abstract*— In this paper, the evaluation of off-grid solar power system for remote self-service banking kiosk in Cross River State is presented. The case study remote self-service banking kiosk is located at Odukpani in Cross River State with latitude of 5.082488, and longitude of 8.348434 and it has daily energy of 206.04 kWh per day. The meteorological data of the case study site consist of mean daily peak sun hour of 6.32 kW-hr/m^2/day and mean daily temperature of 26.00 °C. the results show that the PV system has annual energy yield of 91.9 MWh/yr, performance ratio of 62.7 % and system loss of 0.35 kWh/kWp/day. Also, the PV solar system satisfied the load demand for all the months except in the month of August with the lowest energy yield of about 6262 kWh where there is missing energy of 489.9 kWh with solar fraction of 0.923 , loss of load probability of 7.6% and loss of load duration of 57 hour. Principally, in the month of August, over two days of power outage will be witnessed in the kiosk. Hence, some measures need to be taken to accommodate the two days of power outage. One option is to run the ATM at a fraction of the full load; that means, instead of all the 8 ATMs running 24 hours, the system can be scheduled whereby only 4 out of the 8 run for 24 hours, while the remaining 4 ATMs run 16 hours per day. In this way, power outage can be eliminated in the system all through the year.

Key words: Off-Grid Power, Self-Service Banking Kiosk, Solar Power System, Automatic Teller Machine, Photovoltaic Power

1. INTRODUCTION

Nowadays, many industries are embracing measures to minimize man hour by deploying robots and other self-service mechanisms for their clients. In this wise, banks are increasingly deploying automatic teller machines (ATMs) to provide self-service banking for the bank customers. Accordingly, many banks are deploying self-service banking kiosks to areas closer to their customers. Such areas like markets, city centers and some remote locations with significant customer base are possible locations that many banks do deploy self-service banking kiosks.

In any case, in Nigeria, the major challenge with such self-service banking kiosk is power supply, notably, especially in the remote locations without access to the national grid, providing steady power supply for the self-service banking kiosk is a running challenge. In such situation, solar power has become a viable option for providing off-grid power supply to the self-service banking kiosk. Hence, in this paper, the evaluation of off-grid solar photovoltaic (PV) power system for remote self-service banking kiosk is presented. The evaluation is conducted using PVSyst simulation software. The emphasis of the evaluation is to assess the loss of load performance of the PV power system. Loss of load performance [16,17] parameters include determination of the missing energy, the loss of load probability and the loss of load duration. These parameters are determined using the PVSyst software.

2. METHODOLOGY

The case study remote self-service banking kiosk is located at Odukpani in Cross River State with latitude of 5.082488, and longitude of 8.348434, as shown in Figure 1. The meteorological data of the case study site consist of mean daily peak sun hour of 6.32 kW-hr/m^2/day and mean daily temperature of 26.00 °C. The electric load profile of the self service banking kiosk is given in Table 1 which shows a daily energy of 206.04 kWh per day. The PV system was simulated in the PVSyst software based on the given meteorological data and daily load demand.

The screenshot of PVSyst configuration of the PV power system for remote self-service banking kiosk is shown in Figure 2. The information in Figure 2 shows the selected PV module and the battery and it also shows that the system is designed to have maximum loss of load of 5% and 5 days of power autonomy from the battery bank. The screenshot of PVSyst details of selected PV module are shown in Figure 3. The screenshot in Figure 3 shows that 100 Wp 15 V module model PE 105 manufactured by Mereg is used. It has module area efficiency of 11.56%. Again, the screenshot of PVSyst details of selected battery are shown in Figure 4. The screenshot in Figure 4 shows that 105 Ah 12 V battery model MPG 12V 105 F manufactured by Norada is used. It has stored energy of 1.15kWh at 80 % depth of discharge (DoD).

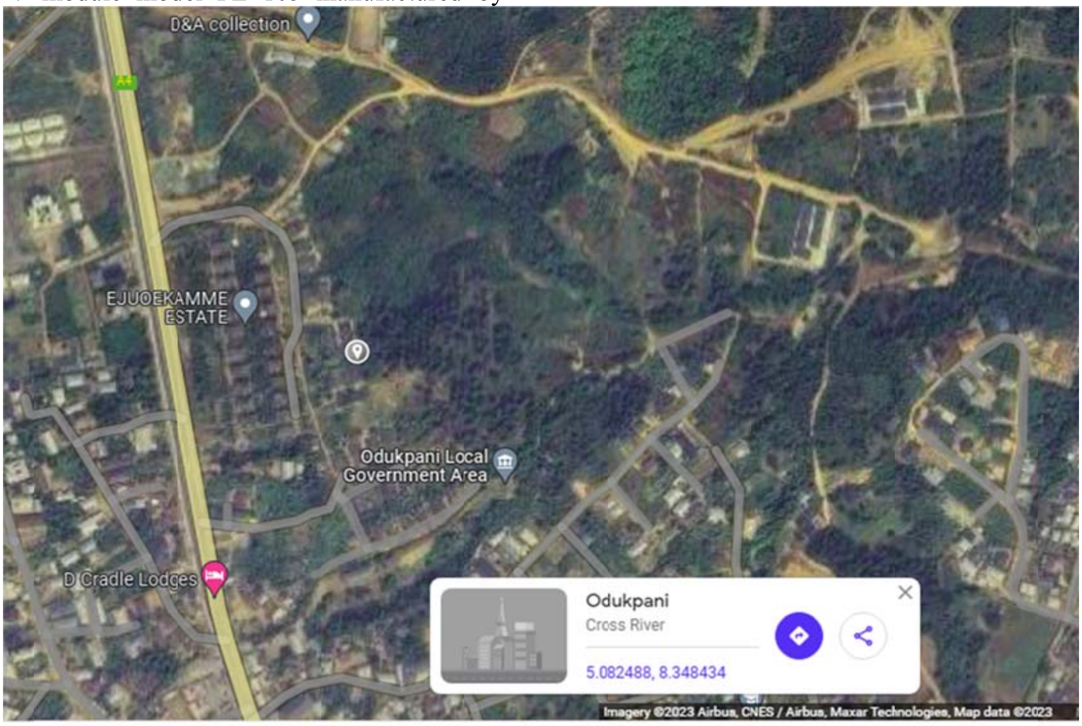

Figure 1 the Google map location of the case study self-service banking kiosk site

Table 1 The electric load profile of the self-service banking kiosk

S/N	Load Description	QTY.	Power (kW)	Duration of operation each day (h)	Total power (kW)	Energy consumption each day (kWh)
1	ATM	8	0.2	24	1.6	38.4
2	CCTV camera	10	0.015	24	0.15	3.6
3	AIR Conditioner	4	1.6	24	6.4	153.6
4	Light for ATM	8	0.03	24	0.24	5.76
5	Hub	1	0.015	24	0.015	0.36
6	Security light	4	0.09	12	0.36	4.32
				TOTAL	8.765	206.04

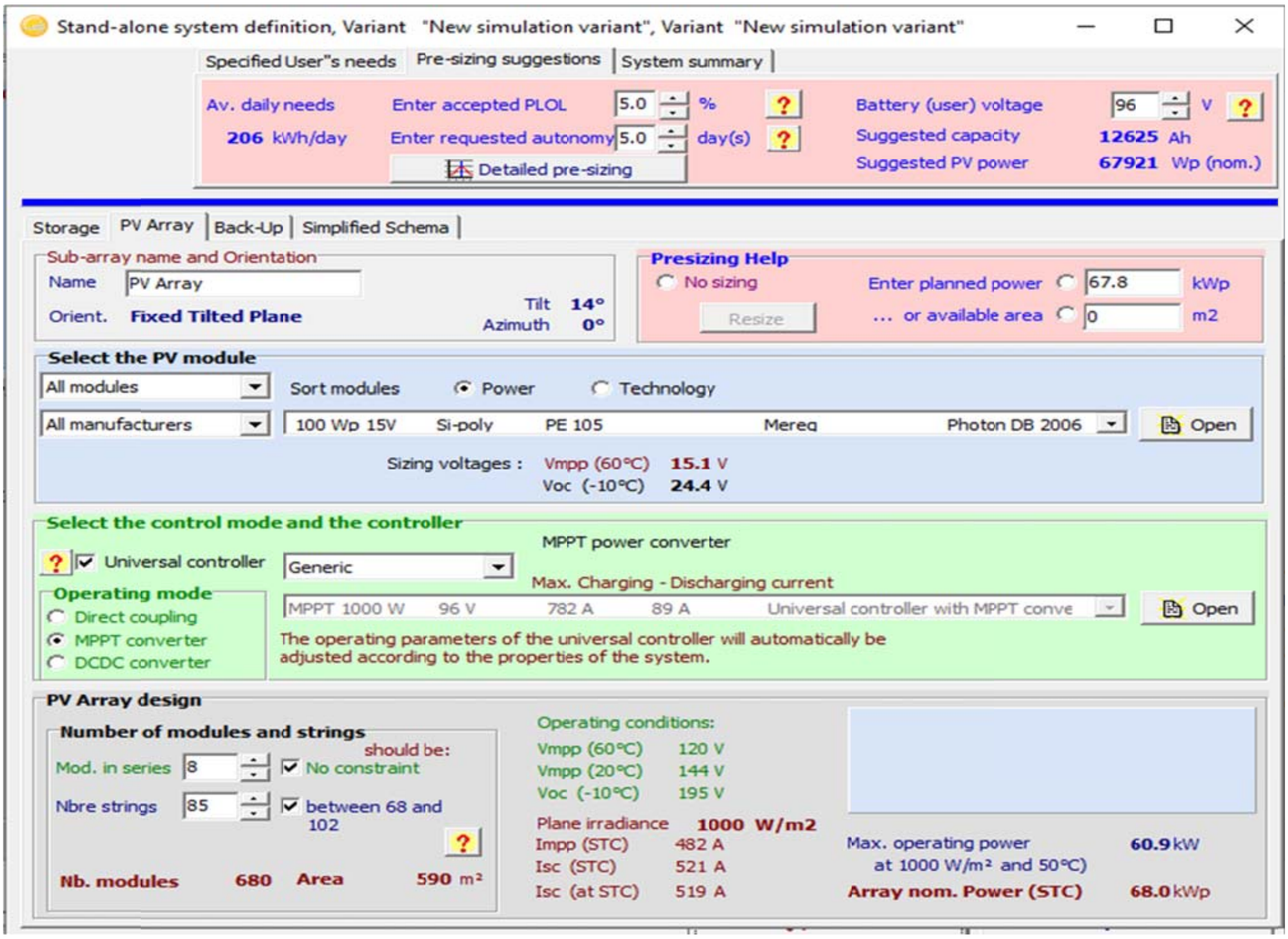

Figure 2 The configuration of the PV power system for remote self service banking kiosk

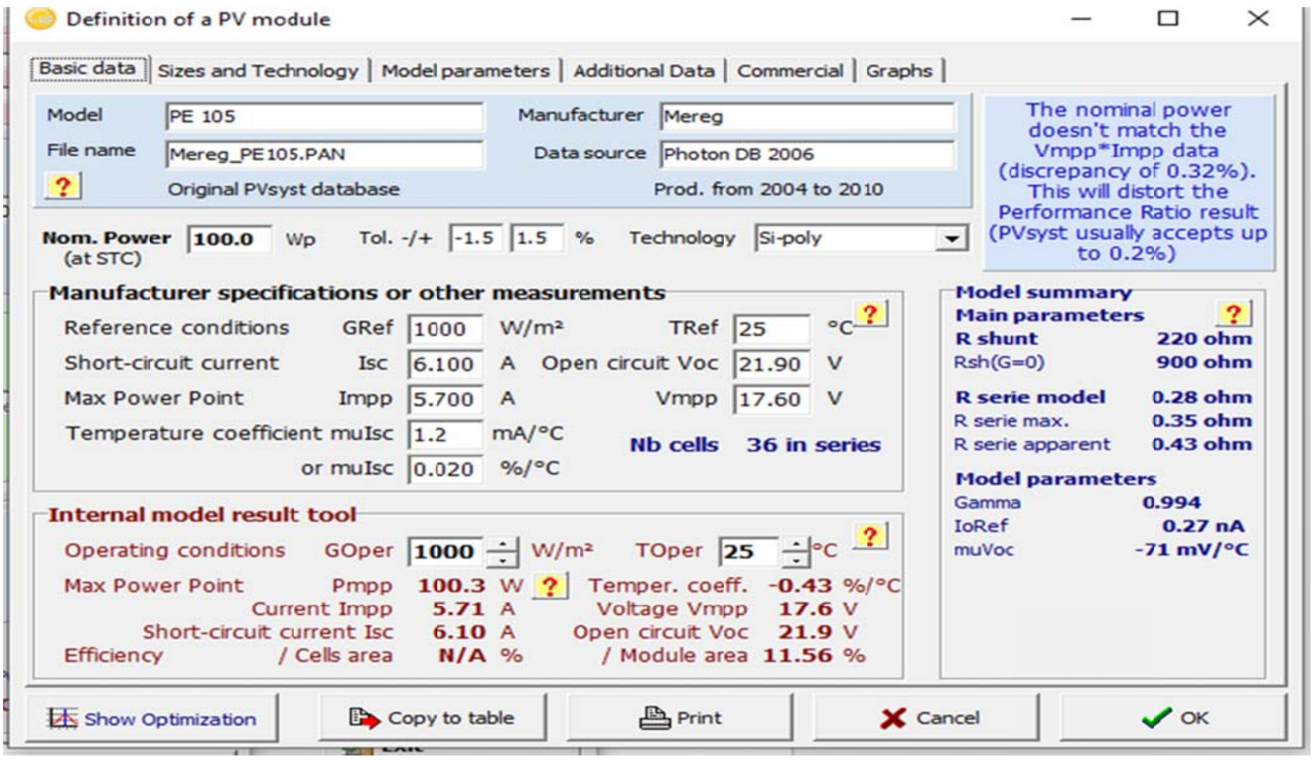

Figure 3 The screenshot of PVSyst details of selected PV module

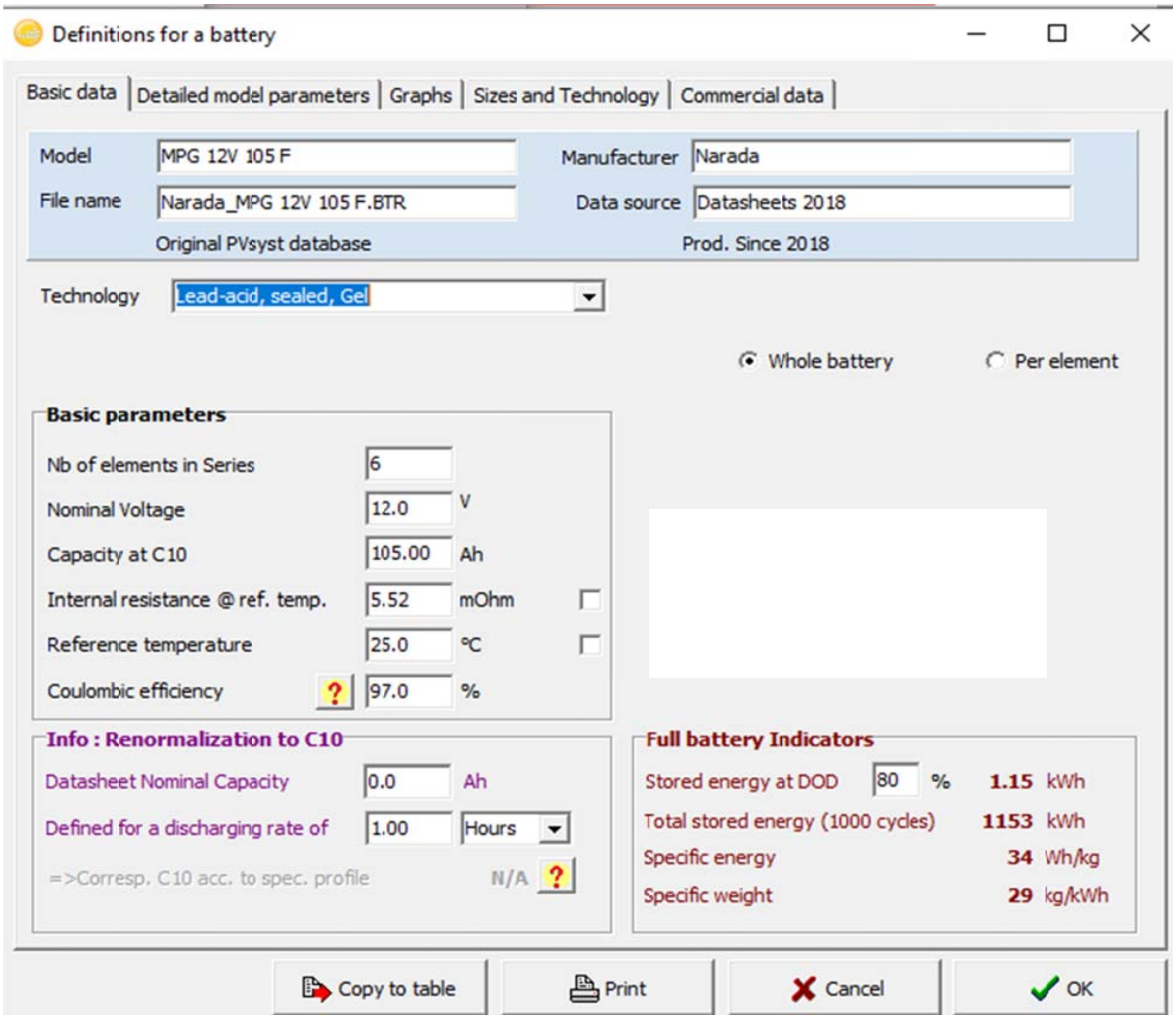

Figure 4 The screenshot of PVSyst details of selected battery

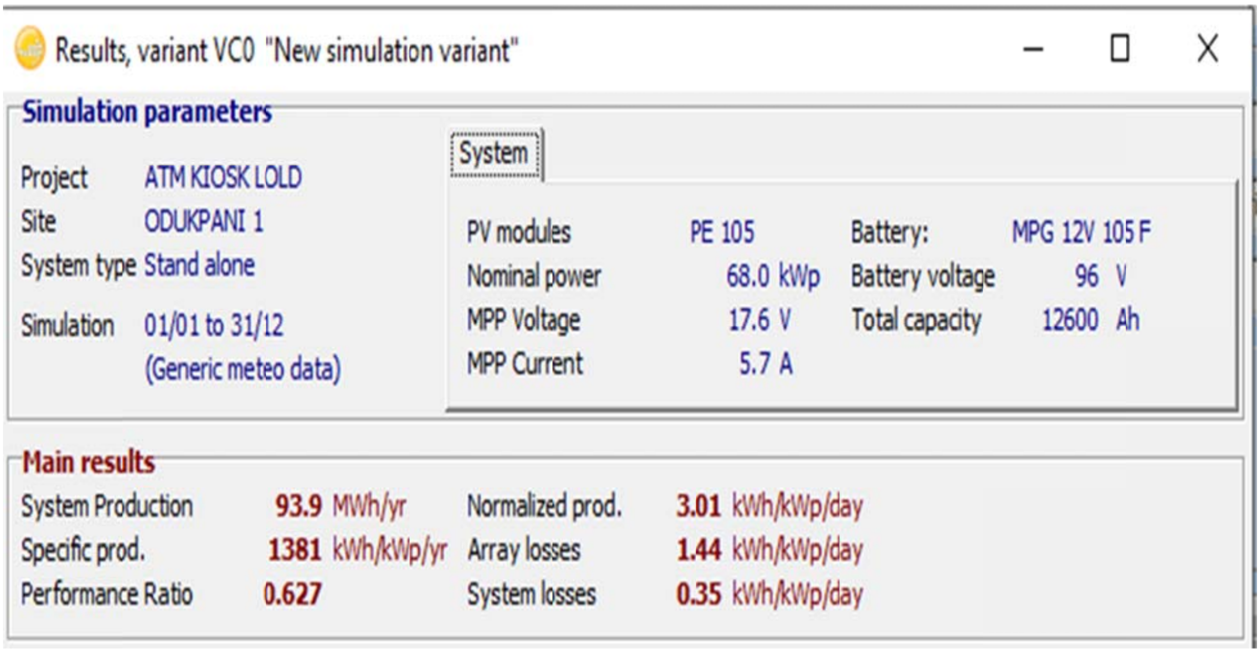

Figure 5 The screenshot of PVSyst results showing the simulation parameters and main results

Table 2 The screenshot of PVSyst results showing the missing energy and solar fraction

	GlobHor kWh/m²	GlobEff kWh/m²	E_Avail kWh	EUnused kWh	E_Miss kWh	E_User kWh	E_Load kWh	SolFrac
January	173.9	189.2	10359	3152	0.0	6387	6387	1.000
February	158.5	165.0	9058	2955	0.0	5769	5769	1.000
March	165.9	162.5	8937	2207	0.0	6387	6387	1.000
April	152.7	141.7	7803	1399	0.0	6181	6181	1.000
May	148.2	130.7	7252	640	0.0	6387	6387	1.000
June	130.8	113.6	6335	92	0.0	6181	6181	1.000
July	120.6	105.9	5991	0	0.0	6387	6387	1.000
August	114.4	104.1	5884	0	489.9	5897	6387	0.923
September	120.3	114.7	6403	1	0.0	6181	6181	1.000
October	133.9	134.2	7368	0	0.0	6387	6387	1.000
November	145.2	153.8	8474	2106	0.0	6181	6181	1.000
December	165.2	181.9	10056	3033	0.0	6387	6387	1.000
Year	1729.5	1697.5	93919	15584	489.9	74715	75205	0.993

Table 3 The screenshot of PVSyst results showing the duration of loss of load and the loss of load probability

	EArray kWh	E_Load kWh	E_User kWh	SolFrac	T_LOL Hour	Pr_LOL %
January	7673	6387	6387	1.000	0	0.00
February	6498	5769	5769	1.000	0	0.00
March	7164	6387	6387	1.000	0	0.00
April	6818	6181	6181	1.000	0	0.00
May	7045	6387	6387	1.000	0	0.00
June	6652	6181	6181	1.000	0	0.00
July	6381	6387	6387	1.000	0	0.00
August	6262	6387	5897	0.923	57	7.62
September	6818	6181	6181	1.000	0	0.00
October	7846	6387	6387	1.000	0	0.00
November	6784	6181	6181	1.000	0	0.00
December	7480	6387	6387	1.000	0	0.00
Year	83421	75205	74715	0.993	57	0.65

The screenshot of PVSyst results showing the simulation parameters and main results are presented in Figure 5. Specifically, Figure 5 shows that the system has annual energy yield of 91.9 MWh/yr, performance ratio of 62.7 % and system loss of 0.35 kWh/kWp/day. The screenshot of PVSyst results showing the missing energy and solar fraction is shown in Table 2. The results in Table 2 show that the solar system satisfied the load demand for all the months except in the month of August where there is missing energy of 489.9 kWh with solar fraction of 0.923. The screenshot of PVSyst results showing the distribution of the energy yield over the year is shown in Figure 6 and it shows that the month of August has the lowest energy yield of about 6262 kWh per month.

The screenshot of PVSyst results showing the duration of loss of load and the loss of load probability is shown in Table 3. It shows that the loss of load duration of 57 hours (as shown also in Figure 7) occurred in the month of August. Now, on annual average, the mean annual loss of load probability of 0.65% was realized but the loss of load probability of 7.6 % occurred in the month of August. This results exceeded the annual average of 5% set as the maximum. This shows that the PVSyst setting of maximum loss of load is for annual average and not the maximum for any month.

Principally, in the month of August, over two days of power outage will be witnessed in the kiosk. Hence, some measures need to be taken to accommodate the two days of power outage. One option is to run the ATM at a fraction of the full load; that means, instead of all the 8 ATMs running 24 hours, the system can be scheduled whereby only 4 out of the 8 run for 24 hours, while the remaining 4 ATMs run 16 hours per day. Essentially, load scheduling is required to eliminate the loss of load in the system.

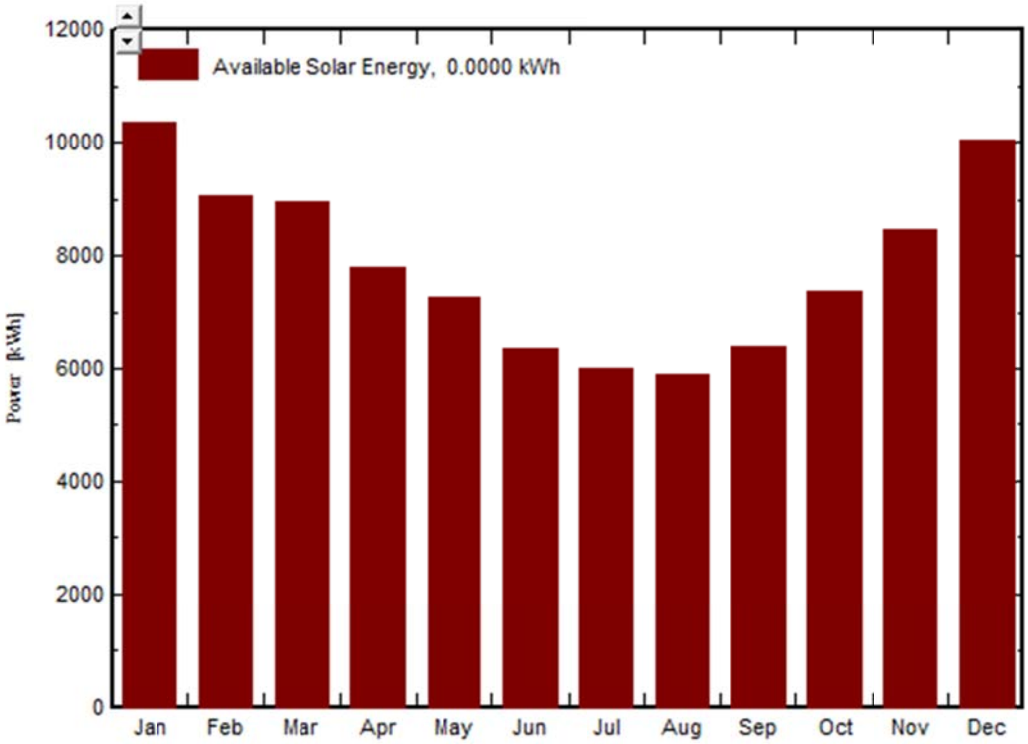

Figure 6 The screenshot of PVSyst results showing the distribution of the energy yield over the year

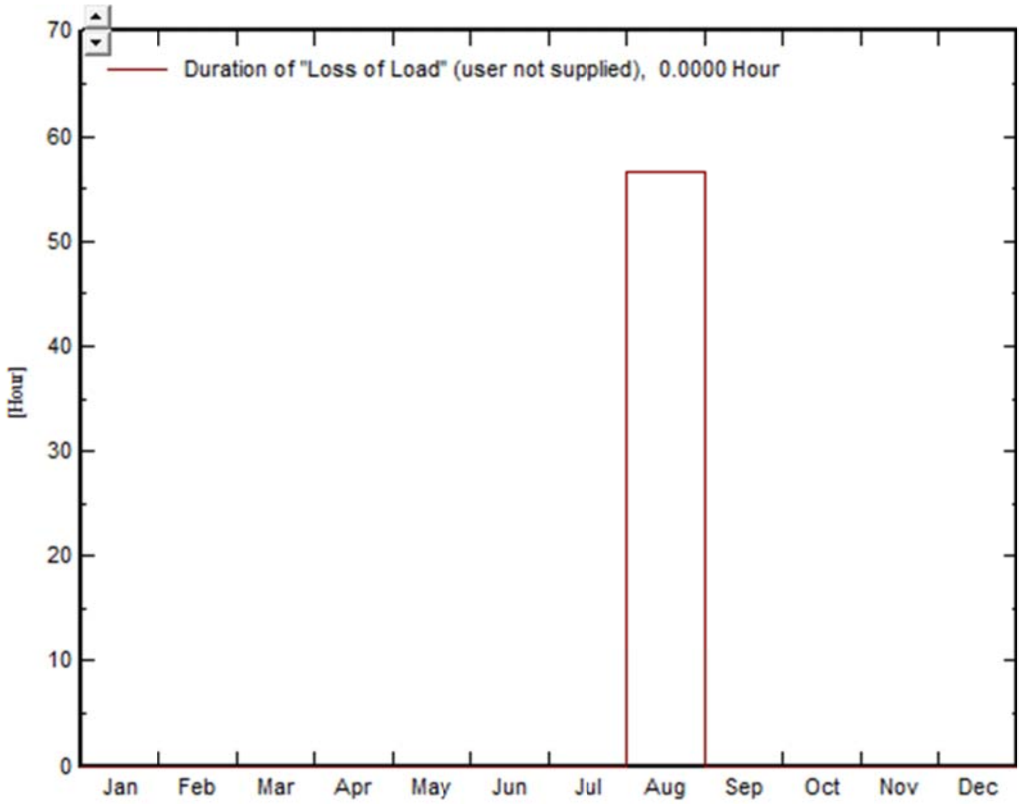

Figure 7 The screenshot of PVSyst results showing the duration of loss of load

3 CONCLUSION

PVSyst software simulation of standalone solar power system for ATM machine kiosk is presented. The focus of the simulation is to carry out evaluation of the energy yield and loss of load performance of the PV power system. The results show that the system is able to supply the required daily load demand except in the month of August which has over two days of power outage. In such case, load scheduling can be used to achieve the desired PV system without any power outage.

REFERENCES

1. Malambo, J. N. (2022). *A critical review of digital innovations challenges on customer satisfaction among financial institutions in Zambia: a case study of Stanbic bank Zambia, Lusaka* (Doctoral dissertation, The University of Zambia).
2. Rajisha, T., & Kumar, S. R. (2020). *Attitudinal precedents in the adoption and usage continuance of technology enabled banking self services a study among bank customers in Kerala* (Doctoral dissertation, Cochin University of Science and Technology).
3. Turi, A. N. (Ed.). (2023). *Financial Technologies and DeFi: A Revisit to the Digital Finance Revolution*. Springer Nature.
4. Kumar, S. This is the age of technology; the Impact of Information Technology Services on Satisfaction Level of customers in banking Sectors. *Recent Trends in Decision Sciences and Their Implications for Business*, 1.
5. Adane, M. D., Wale, T., & Meried, E. W. (2021). Determinants of automated teller machine deployment in commercial banks of Ethiopia. *Heliyon*, *7*(8).
6. Ahmad, U. H. (2023). The Relationship between the growth in Automated Teller Machine (ATM) terminal and values of ATM services in Nigeria.
7. EWANLEN, D. O., & MADUMERE, I. (2021). Customers Coping Strategies with Banks Automated Teller Machines (ATM) Service Failures.
8. ADEGOKE, N., & EBOBO, U. (2020). THE IMPACT OF AUTOMATED TELLER MACHINES (ATM) FRAUDS ON BANKS'CUSTOMERS IN NIGERIA. *FULafia Journal of Social Sciences*, *3*(2), 1-13.
9. Aljuaid, S. M., & Ansari, A. S. (2022). Automated Teller Machine Authentication Using Biometric. *Comput. Syst. Sci. Eng.*, *41*(3), 1009-1025.
10. Nwannunu, S. E. (2020). Automated Teller Machines (ATMS) Services And Customer Satisfaction. *BAKOLORI JOURNAL OF GENERAL STUDIES*, *10*(2), 2749-2770.
11. Aidonojie, P. A., Ikubanni, O. O., & Okuonghae, N. (2022). The prospects, challenges, and legal issues of digital banking in Nigeria. *Cogito: Multidisciplinary Res. J.*, *14*, 186.
12. Nwekpa, K. C., Djobissie, I. C., Chukwuma, N. N., & Ezezue, B. O. (2020). Influence of electronic banking on customer satisfaction in a Fidelity Bank Plc in Nigeria. *IOSR Journal of Business and Management*, *22*, 49-58.
13. Ediagbonya, V., & Tioluwani, C. (2023). The role of fintech in driving financial inclusion in developing and emerging markets: issues, challenges and prospects. *Technological Sustainability*, *2*(1), 100-119.
14. Idowu, S. S., Ibietan, J., & Olukotun, A. (2019). Nigeria's electricity power sector reform: an appraisal of unresolved issues. *International Journal of Energy Economics and Policy*, *9*(6), 336-341.
15. Ogbuabor, J. E., Eigbiremolen, G. O., Orji, A., Manasseh, C. O., & Onuigbo, F. N. (2020). ICT and financial inclusion in Nigeria: An overview of current challenges and policy options. *Nigerian Journal of Banking and Finance*, *12*(1), 90-96.
16. Hlal, M. I., Ramachandaramurthy, V. K., Sarhan, A., Pouryekta, A., & Subramaniam, U. (2019). Optimum battery depth of discharge for off-grid solar PV/battery system. *Journal of Energy Storage*, *26*, 100999.
17. Sanajaoba, S. (2019). Optimal sizing of off-grid hybrid energy system based on minimum cost of energy and reliability criteria using firefly algorithm. *Solar Energy*, *188*, 655-666.