Rooftop Grid-connected automated teller machine PV solar power system analysis

Eduediuyai Ekerette Dan[1]
Department of Computer Engineering Federal Polytechnic, Ukana
Akwa Ibom State Nigeria
uyaiabasidan@gmail.com

Oto-Obong Chijioke Onwunali[2]
Department of Electrical Electronic and Computer Engineering University of Uyo
Akwa Ibom State, Nigeria.

Mbom, Samuel Etaruwak[3]
Department of Computer Engineering
Ihechukwu Madubuike Institute of Technology, Abia State

***Abstract*— In this paper, rooftop grid-connected automated teller machine (ATM) PV solar power system analysis is presented. The analytical expressions for computing the energy produced from the rooftop area are presented along with some expressions that are used to account for losses in the system. The case study ATM consumes about 92.64 kWh of energy per day. The optimal tilt angle for the PV array is 9° and the PV array is fixed at that angle all through the year. The PV module selected for the power system is the 13V 50 Wp Siemens Solar PV module with model number M50. The PV power system consists of 3 kWac inverter with 56 PV modules which occupies a total area of 22.5 m^2.The results show that the PV power system has a performance ratio of 78.58% and solar fraction is 11.27%. That means only 11.27 % of the total energy demand of the ATM machine is supplied from the PV solar power. Hence, he remaining 88.73 % of the ATM energy demand comes from the grid power supply.**

Keywords*— *Rooftop Solar power, Grid-connected solar power, Automated Teller Machine (ATM) , Photovoltaic (PV) solar power system, PVSyst

1. Introduction

Solar power system has dominated the green alternative power sources in Nigeria [1,2,34,5,6, 7,8,9, 10,11, 12,13, 14, 15, 16]. It has witnessed widespread adoption across Nigeria due to the availability of solar radiation and the steady drop in the relative cost of the solar power system when compared to the cost of diesel and other fossil fuel generating sets [17,18,19,20,21,22,3,24,25]. In any case, the rising installation base is also due to increasing demand for energy without corresponding improvement in the energy generation and supply from the national grid [26,27,28,29,30,31,32,33,34,35,36,37,38]. Rather, the cost of energy from the national grid is increasing without meaningful improvement in the quality and quantity of power supply form the grid [39,40]. As such, the situation is driving more consumers to look for other alternative energy supply systems to address the perennial and ever increasing energy shortage across Nigeria [41,42,43].

Accordingly, in this paper, sizing and analysis of rooftop grid-connected automated teller machine (ATM) PV solar power system is presented [44,45,46]. The focus on ATM is timely as the cashless policy of the Federal government has prompted many people to patronize banks and their ATM which is for self-service banking outlet. Importantly, ATM is expected to render all-day round service to the bank customers [47,48,49,50,51,52]. As such, steady and reliable power supply is required for effective service delivery to the bank customers. Such reliable power supply system can easily be achieved with a solar PV power system with properly sized solar panels and storage battery bank. This paper presents the approach to properly size a rooftop solar power system for an ATM machine. The popular PVSyst solar power simulation software is used for the sizing and analysis of the grid connected rooftop solar power system.

2. Methodology

2.1 The basic equations for rooftop solar PV power system analysis

The study is mainly to analyse the rooftop grid-connected PV solar power for an automated teller machine (AMT) that serves as a self-service banking outlet for clients of financial institutions. The energy produced from a given rooftop area (A_{TRF}) depends on (A_{PVT}) the actual area used on the roof for PV array installation and some roof factors denoted as f_o for roof inclination and f_s for unused roof area, where;

$$f_o = (f_{flat})(r_{flat}) + (f_{peak})(r_{peak}) \quad (1)$$

r_{flat} = 1 for flat roof and r_{peak} = 0.5 for peaked roof. Also, $0.3 \le f_s \le 0.9$), then;

$$A_{PVT} = (f_o)(f_s)(A_{TRF}) \quad (2)$$

The optimal angle, β_{opt} for tilting the solar panel is given as

$$\beta_{opt} = 3.7 + 0.69|\varphi| \quad (3)$$

Where φ represents the latitude of the PV installation site.

The daily energy consumption of the load which can be supplied by PV array with area of A_{PVT}, mean daily global solar irradiation on the PV module plane (denoted as G_d), operating efficiency of the PV module (denoted as η_{pv}), overall DC to AC de-rating factor denoted as $f_{dc/ac}$ (typical value is 0.85) and temperature de-rating factor denoted as f_{temp} is given as;

$$E_L = A_{pv} (G_d * \eta_{pv} * f_{dc/ac} * f_{temp}) \quad (4)$$

Where

$$f_{temp} = 1 - (\gamma_{pv} * (T_a - T_{STC})) \quad (9)$$

$$T_{cell} = T_a + \left(\frac{\alpha(G_d)(1-\eta_{PVSTC})}{U_0 + U_1 (V_{wind})}\right) \quad (6)$$

Based on (E_L) the daily energy consumption of the load and (A_{PVT}) the actual area used on the roof for PV array installation the PVSyst is used to select PV modules and determine the number of the modules that make up the PV array for the PV solar power system. Further analysis of the solar power system with the PVSyst will yield other essential energy generation and consumption related performance parameters.

2.2 The case study dataset for the daily load and daily solar irradiation

The energy consumption data for the Automated Teller Machine (ATM) is shown in Table 1 and the monthly mean solar irradiation and ambient temperature data for the ATM machine is shown in Table 2. Based on the data in Table 1, the ATM consumes about 92.64 kWh of energy per day. The screenshot from PVSyst showing the hourly distribution of the ATM load is shown in Figure 1 while the screenshot of the PVSyst visual display of the hourly distribution of the daily energy demand is shown in Figure 2. Also, the monthly mean solar irradiation and ambient temperature data for the ATM machine installation site is shown in Table 1.

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	ATM	2	0.7	24	1.4	33.6
2	AIR Conditioner	1	1.6	24	1.6	38.4
3	Lightings	6	0.09	24	0.54	12.96
4	Hub	1	0.32	24	0.32	7.68
	Total Energy Consumed				3.86	92.64

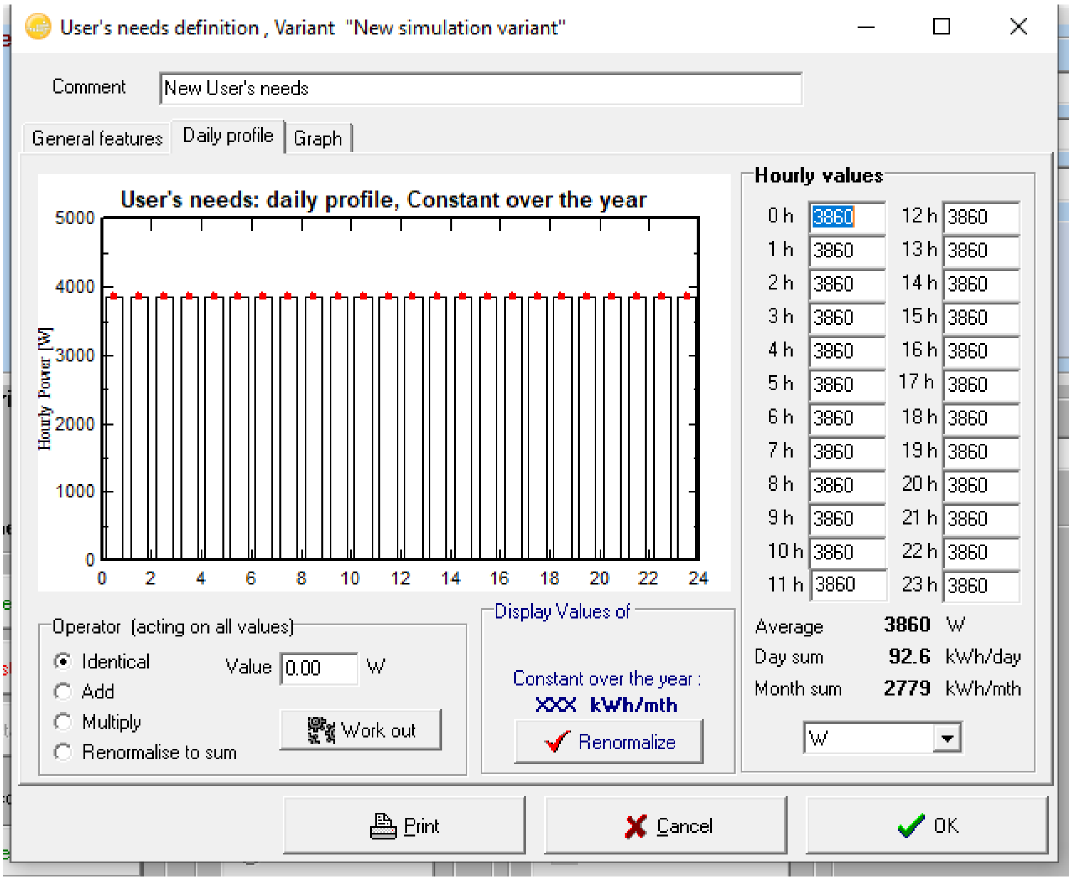


Figure 2 The screenshot from PVSyst showing the hourly distribution of the ATM load

Table 2 The monthly mean solar irradiation and ambient temperature data for the ATM machine

Meteo for AKWA IBOM STATE - Synthetically Generated Data

Plane: tilt 9°, azimuth 0°, Albedo 0.20

Interval beginning	GlobHor kWh/m².mth	DiffHor kWh/m².mth	GlobInc (Hay model) kWh/m².mth	T Amb °C
January	171.4	53.63	183.1	25.3
February	156.5	55.16	162.6	25.8
March	164.9	68.82	165.9	25.7
April	152.7	68.10	149.1	25.8
May	146.3	67.58	139.5	25.7
June	129.3	63.30	122.2	24.8
July	119.3	66.03	114.1	24.1
August	116.9	68.20	113.7	23.9
September	118.2	68.10	117.7	24.2
October	132.4	67.27	134.7	24.5
November	145.2	58.50	153.1	24.7
December	164.0	53.01	176.6	24.7
Year	1717.2	757.70	1732.2	24.9

3. Results and discussion

The screenshot of the PVSyst dialogue box for the PV panel optimal orientation is shown in Figure 3 while the schematic diagram of the grid-connected solar power system is shown in Figure 4. As shown in Figure 3, the optimal tilt angle for the PV array is 9° and the PV array is fixed at that angle all through the year. The screenshot of the PVSyst dialogue box for sizing of the PV array and inverter is shown in Figure 5. According to Figure 5, the PV module selected is the 13V 50 Wp Siemens Solar PV module with model number M50. The details of the PV module is further shown in Figure 6.

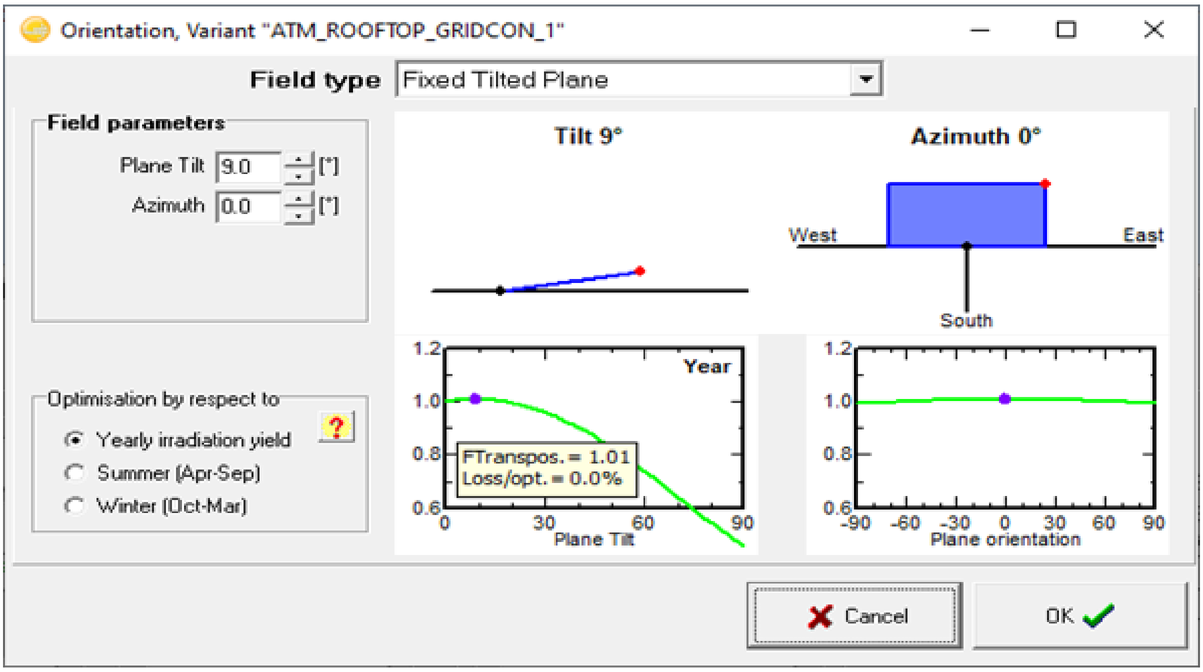


Figure 3 The screenshot of the PVSyst dialogue box for the PV panel optimal orientation

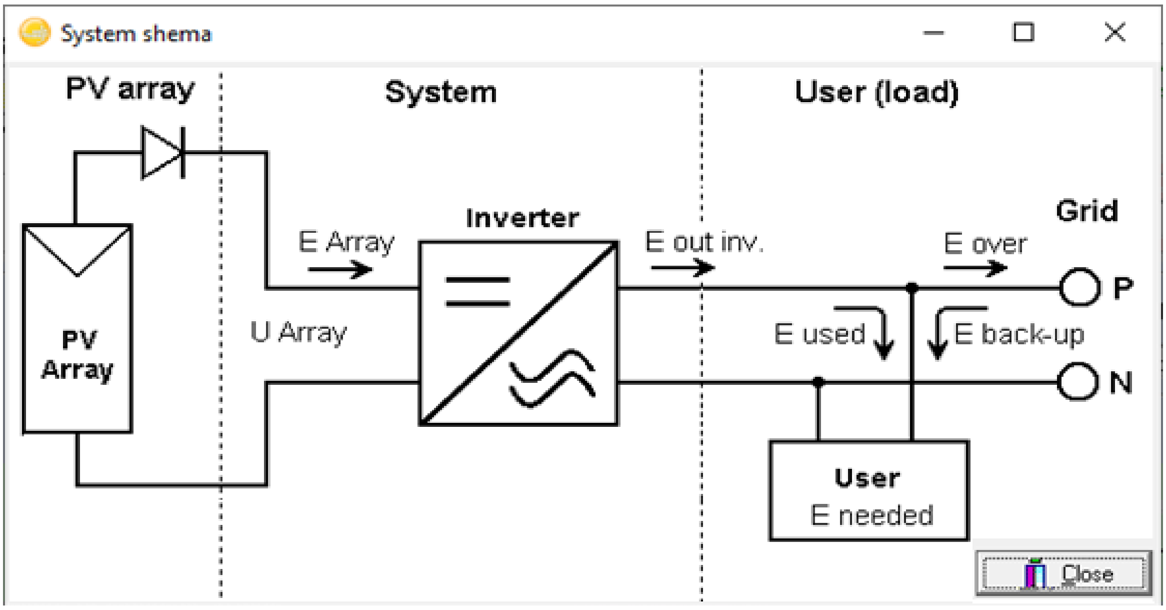


Figure 4 The screenshot of the PVSyst schematic diagram of the grid-connected solar power system is shown in.

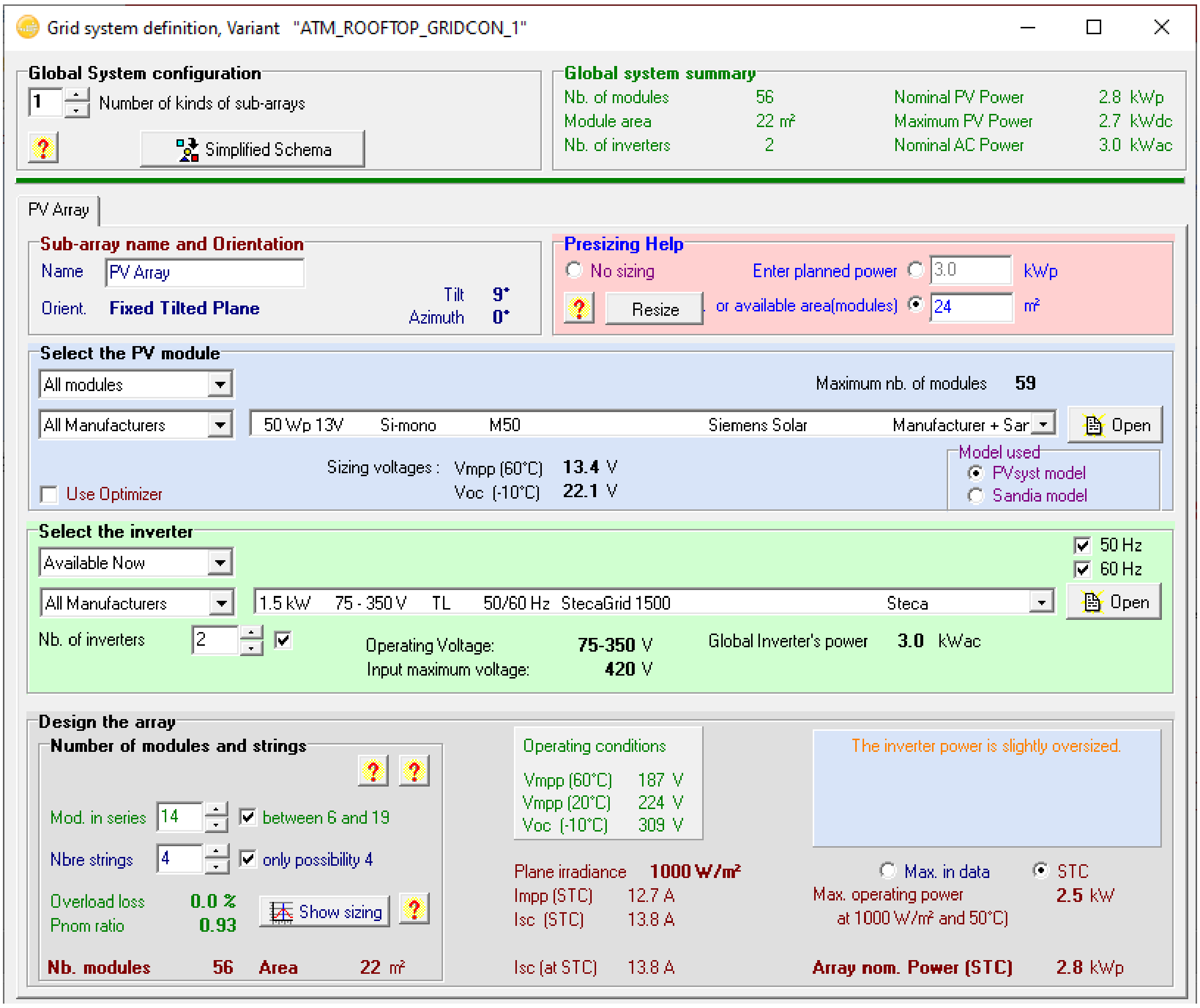


Figure 5 The screenshot of the PVSyst dialogue box for sizing of the PV array and inverter

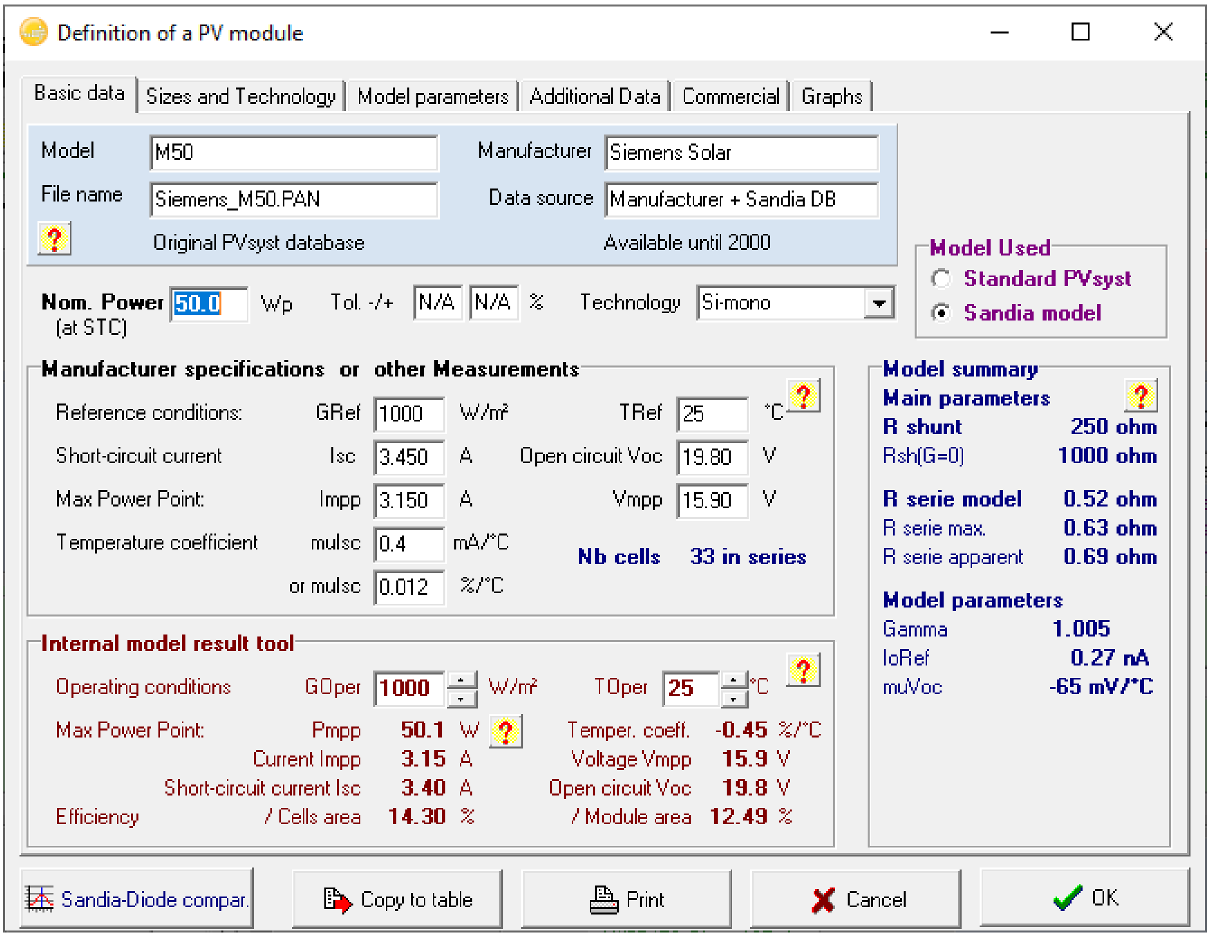


Figure 6 The details of the 13V 50 Wp Siemens Solar PV module with model number M50.

Figure 7 The details of the ATM machine energy demand as it was used in the PVSyst simulation .

PVSYST V6.70			30/12/22	Page 1/4
Grid-Connected System: Simulation parameters				
Project :		**ATM_ROOFTOP_GRIDCONN**		
Geographical Site		**AKWA IBOM STATE**	Country	**Nigeria**
Situation	Latitude	5.05° N	Longitude	7.90° E
Time defined as	Legal Time	Time zone UT	Altitude	56 m
	Albedo	0.20		
Meteo data:	**AKWA IBOM STATE**	NASA-SSE satellite data, 1983-2005 - Synthetic		
Simulation variant :		**ATM_ROOFTOP_GRIDCON_1**		
	Simulation date	30/12/22 02h27		
Simulation parameters	System type	**No 3D scene defined**		
Collector Plane Orientation	Tilt	9°	Azimuth	0°
Models used	Transposition	Hay	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			
PV Array Characteristics				
PV module Si-mono	Model	**M50**		
Original PVsyst database	Manufacturer	Siemens Solar		
Number of PV modules	In series	14 modules	In parallel	4 strings
Total number of PV modules	Nb. modules	56	Unit Nom. Power	50 Wp
Array global power	Nominal (STC)	**2800 Wp**	At operating cond.	2490 Wp (50°C)
Array operating characteristics (50°C)	U mpp	196 V	I mpp	13 A
Total area	Module area	**22.5 m²**	Cell area	19.6 m²
Inverter	Model	**StecaGrid 1500**		
Original PVsyst database	Manufacturer	Steca		
Characteristics	Operating Voltage	75-350 V	Unit Nom. Power	1.50 kWac
Inverter pack	Nb. of inverters	2 units	Total Power	3.0 kWac
			Pnom ratio	0.93
PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	257 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	3.0 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05

Figure 8 The screenshot of the PVSyst simulation parameters for the ATM machine

The details of the ATM machine energy demand as it was used in the PVSyst simulation is shown in Figure 7 while the screenshot of the PVSyst simulation parameters for the ATM machine. According to Figure 8, the inverter consists of two units of 1.5 kWac inverters which amounts to 3 kWac inverter. Also, according to the parameters in Figure 8, the PV array consists of 56 PV modules which occupies a total area of 22.5 m^2. The main results of the PVSyst simulation for the ATM machine solar power system are shown in Figure 9. According to the results in Figure 9, the ATM PV power system has a performance ratio of 78.58%. This means that about 21.42 % (that is, 100 -78.58 %) are lost due to several factors, as shown in the loss diagram of Figure 10. Hence, only the 78.58 % of the energy produced by the PV array that is delivered to the ATM machine. Also, the results in Figure 9 and Table 2 show that the solar fraction is 11.27%. That means only 11.27 % of the total energy demand of the ATM machine is supplied from the PV solar power. Hence, he remaining 88.73 % of the ATM energy demand comes from the grid power supply.

PVSYST V6.70	30/12/22	Page 3/4

Grid-Connected System: Main results

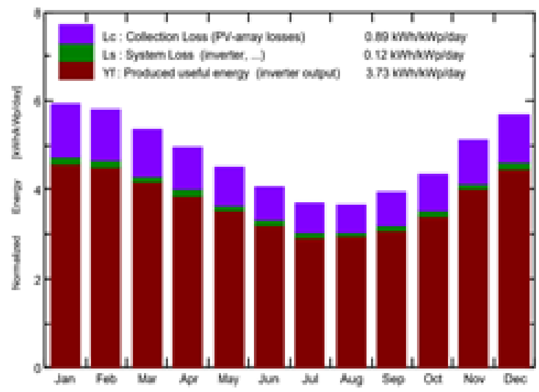
Project : **ATM_ROOFTOP_GRIDCONN**

Main simulation results

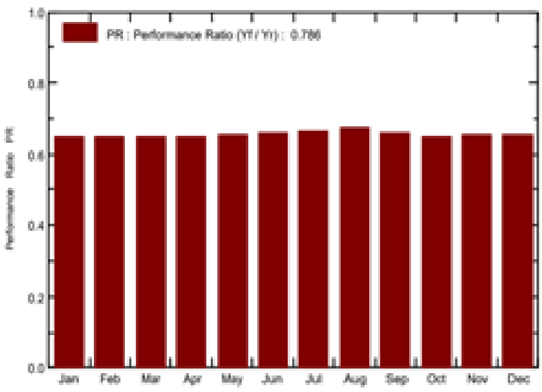
System Production — **Produced Energy** **3811 kWh/year** — Specific prod. 1361 kWh/kWp/year

Performance Ratio PR 78.58 % — Solar Fraction SF 11.27 %

Normalized productions (per installed kWp): Nominal power 2800 Wp



Performance Ratio PR



ATM_ROOFTOP_GRIDCON_1

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	E Load kWh	E User kWh	E_Grid kWh
January	171.4	53.63	25.35	183.1	178.0	2872	399.7	0.000
February	156.5	55.16	25.76	162.6	158.0	2594	353.7	0.000
March	164.9	68.82	25.68	165.9	160.9	2872	362.7	0.000
April	152.7	68.10	25.77	149.1	144.2	2779	325.7	0.000
May	146.3	67.58	25.65	139.5	134.5	2872	307.5	0.000
June	129.3	63.30	24.77	122.2	117.5	2779	269.9	0.000
July	119.3	66.03	24.05	114.1	109.7	2872	253.8	0.000
August	116.9	68.20	23.94	113.7	109.3	2872	257.0	0.000
September	118.2	68.10	24.15	117.7	113.6	2779	260.8	0.000
October	132.4	67.27	24.45	134.7	130.2	2872	294.6	0.000
November	145.2	58.50	24.68	153.1	148.3	2779	337.4	0.000
December	164.0	53.01	24.70	176.6	171.5	2872	388.5	0.000
Year	1717.2	757.70	24.91	1732.2	1675.7	33814	3811.3	0.000

Legends:

GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation	E Load	Energy need of the user (Load)
T Amb	Ambient Temperature	E User	Energy supplied to the user
GlobInc	Global incident in coll. plane	E_Grid	Energy injected into grid

Figure 9 The main results of the PVSyst simulation for the ATM machine solar power system

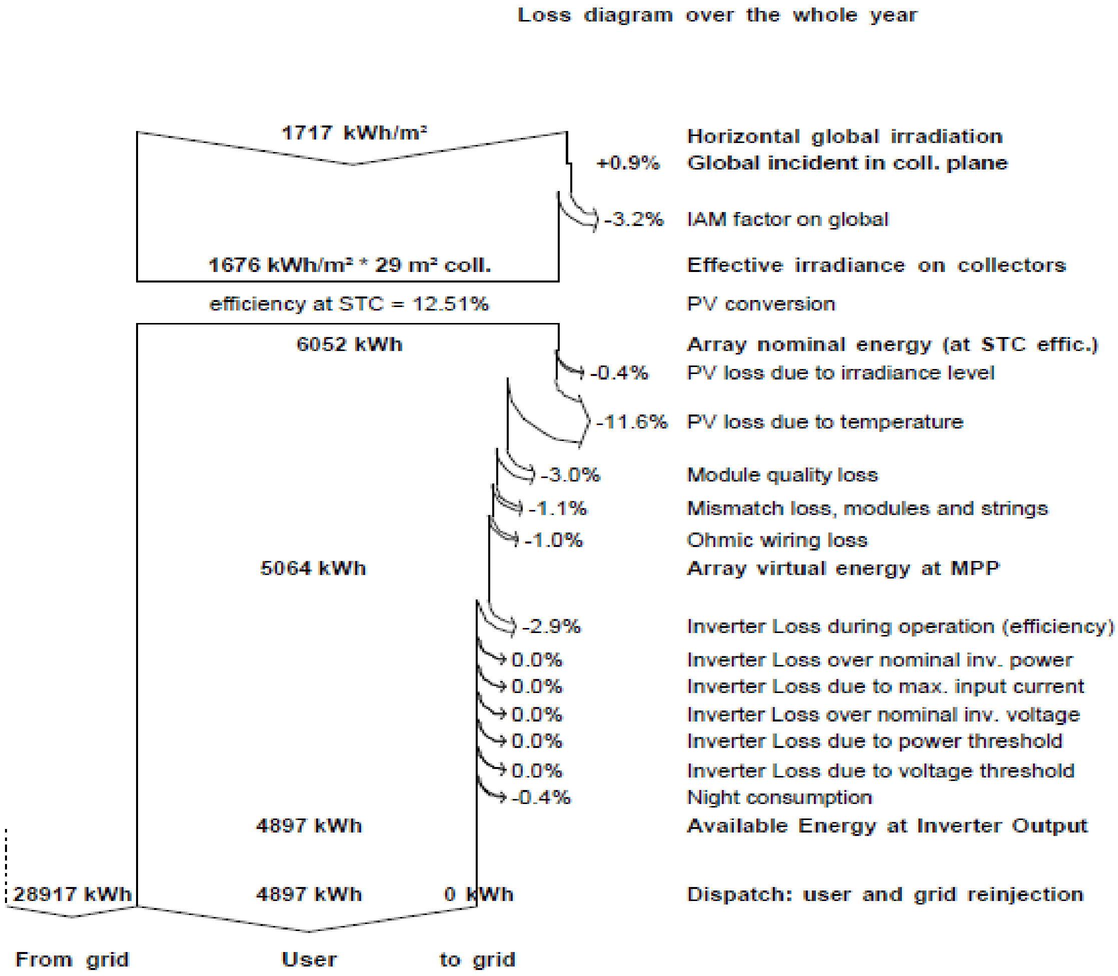


Figure 10 The loss diagram showing the various losses in the ATM PV power system

Table 2 The PVSyst results on the energy use in the system

ATM_ROOFTOP_GRIDCON_1

Energy use and User's needs

	E Avail kWh	E Load kWh	E User kWh	E_Grid kWh	SolFrac
January	399.7	2872	399.7	0.000	0.139
February	353.7	2594	353.7	0.000	0.136
March	362.7	2872	362.7	0.000	0.126
April	325.7	2779	325.7	0.000	0.117
May	307.5	2872	307.5	0.000	0.107
June	269.9	2779	269.9	0.000	0.097
July	253.8	2872	253.8	0.000	0.088
August	257.0	2872	257.0	0.000	0.089
September	260.8	2779	260.8	0.000	0.094
October	294.6	2872	294.6	0.000	0.103
November	337.4	2779	337.4	0.000	0.121
December	388.5	2872	388.5	0.000	0.135
Year	3811.3	33814	3811.3	0.000	0.113

4 Conclusion

The rooftop PV power system for an automated teller machine is studied. The daily energy demand of the ATM was determined and the solar radiation data of the location was acquired. The PVsyst software was used to size the PV power system and also to analyze its performance in terms of performance ratio, solar fraction, and system loss contents. The results showed that less than 12 %of the total energy demand is derived from the solar power system. Also, over 21 %of the energy produced from the solar power system are lost due to various factors.

References

1. Williams, E. A., Raimi, M. O., Yarwamara, E. I., & Modupe, O. (2019). Renewable Energy Sources for the Present and Future: An Alternative Power Supply for Nigeria. *Ebuete Abinotami Williams, Raimi Morufu Olalekan, Ebuete Ibim Yarwamara & Oshatunberu Modupe (2019) Renewable Energy Sources for the Present and Future: An Alternative Power Supply for Nigeria. Energy and Earth Science*, *2*(2).

2. Archibong, Ekaette Ifiok, Simeon Ozuomba, and Etinamabasiyaka Ekott. (2020) "Internet of things (IoT)-based, solar powered street light system with anti-vandalisation mechanism." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020.
3. Umoette, A. T., Ozuomba, Simeon, & Okpura, N. I. (2017). Comparative Analysis of the Solar Potential of Offshore and Onshore Photovoltaic Power System. *Mathematical and Software Engineering*, *3*(1), 124-138
4. Oyewo, A. S., Aghahosseini, A., Bogdanov, D., & Breyer, C. (2018). Pathways to a fully sustainable electricity supply for Nigeria in the mid-term future. *Energy Conversion and Management*, *178*, 44-64.
5. Idorenyin Markson, Simeon Ozuomba, Iniobong Edifon Abasi-Obot (2019) Sizing of Solar Water Pumping System for Irrigation of Oil Palm Plantation in Abia State. *Universal Journal of Engineering Science* 7(1): 8-19, 2019
6. Ohunakin, O. S. (2010). Energy utilization and renewable energy sources in Nigeria. *Journal of Engineering and Applied Sciences*, *5*(2), 171-177.
7. Ikpe Joseph Daniel, Ozuomba Simeon, Udofia Kufre (2019) Google Map-Based Rooftop Solar Energy Potential Analysis For University Of Uyo Main Campus . *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 7, July - 2019*
8. Simeon, Ozuomba.(2019) "An assessment of solar-powered soybean farm basin irrigation water supply system." *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 4, April - 2019*

9. Archibong, Ekaette Ifiok, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Design And Construction Of The Circuits For An Iot-Based, Stand-Alone, Solar Powered Street Light With Vandalisation Monitoring And Tracking Mechanism." *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 7, July - 2020*

10. Lemene B. Deele, Ozuomba, Simeon, Nseobong Okpura (2020). Comparative Life Cycle Cost Analysis Of Off-Grid 200 KW Solar-Hydro Power Plant With Pumped Water Storage And Solar Power Plant With Battery Storage Mechanism *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 8, August - 2020*

11. Usah, Emmamuel Okon, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Design And Construction Of Circuits For An Integrated Solar-Wind Energy *System With Remote Monitoring And Control Mechanism." Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 6, June - 2020*
12. Deele, L. B., Ozuomba, Simeon, & Okpura, N. (2019). Design and Parametric Analysis of a Stand-Alone Solar-Hydro Power Plant with Pumped Water Storage Technology. *International Journal of Engineering & Technology, 4(1), 9-23.*
13. Ozuomba, Simeon, Edifon, Iniobong, and Idorenyin Markson (2019). Impact of the optimal tilt angle on the solar photovoltaic array size and cost for A 100 Kwh solar power system In Imo State. International *Journal of Sustainable Energy and Environmental Research, 8(1), 29-35.*

14. Usah, Emmamuel Okon, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Spatial Regression Models For Characterizing The Distribution Of Peak Sun Hours, PV Daily Energy Yield And Storage Battery Capacity For Standalone Photovoltaic (PV) Installations Across Nigeria." Delta 5, no. 5.808841: 4-53. *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 7, July – 2020*

15. Archibong, E. I., Ozuomba, Simeon, & Ekott, E. E. (2020). Life Cycle Cost And Carbon Credit Analysis For Solar Photovoltaic Powered Internet Of Things-Based Smart Street Light In *Uyo. International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 1, January - 2020*

16. Simeon, Ozuomba, Kalu Constance, and Okon Smart Essang (2020). Assessment Of The Effect Of The Water Pump Connection Configuration On The Electric Power Demand For A Solar Powered Groundnut Farm Furrow Irrigation System *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 9, September - 2020*
17. Ho, S. M., Lomi, A., Okoroigwe, E. C., & Urrego, L. R. (2019). Investigation of solar energy: The

case study in Malaysia, Indonesia, Colombia and Nigeria. *International Journal of Renewable Energy Research*, *9*(1).

18. Kumar, N. M., Singh, A. K., & Reddy, K. V. K. (2016). Fossil fuel to solar power: a sustainable technical design for street lighting in Fugar City, Nigeria. *Procedia Computer Science*, *93*, 956-966.

19. Usah, Emmamuel Okon, Simeon Ozuomba, Enobong Joseph Oduobuk, and Etinamabasiyaka Edet Ekott. (2020). "Development Of Analytical Model For Characterizing A 2500 W Wind Turbine Power Plant Under Varying Climate Conditions In Nigeria." *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 6, June - 2020*

20. Lemene B. Deele, Ozuomba, Simeon, Okon Smart Essang (2020) SIZING OF AN OFF-GRID PHOTOVOLTAIC POWER SUPPLY SYSTEM WITH BATTERY STORAGE *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 8, August - 2020*

21. Okoye, C. O., Taylan, O., & Baker, D. K. (2016). Solar energy potentials in strategically located cities in Nigeria: Review, resource assessment and PV system design. *Renewable and Sustainable Energy Reviews*, *55*, 550-566.

22. Archibong, Ekaette Ifiok, Ozuomba, Simeon, Etinamabasiyaka Edet Ekott (2020) "Sizing Of Stand-Alone Solar Power For A Smart Street Light System With Vandalisation Monitoring And Tracking Mechanism." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 7, July - 2020*

23. Agbo, E. P., Edet, C. O., Magu, T. O., Njok, A. O., Ekpo, C. M., & Louis, H. (2021). Solar energy: A panacea for the electricity generation crisis in Nigeria. *Heliyon*, *7*(5), e07016.

24. Usah, Emmamuel Okon, Simeon Ozuomba, Enobong Joseph Oduobuk (2020). "Pvsyst Software-Based Comparative Techno-Economic Analysis Of PV Power Plant For Two Installation Sites With Different Climatic Conditions." *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 7, July - 2020*

25. Victor Etop Sunday, Ozuomba Simeon and Umoren Mfonobong Anthony (2016). Multiple Linear Regression Photovoltaic Cell Temperature Model for PVSyst Simulation Software, International Journal of Theoretical and Applied Mathematics, 2(2): pp. 140-143

26. Dada, J. O. (2014). Towards understanding the benefits and challenges of Smart/Micro-Grid for electricity supply system in Nigeria. *Renewable and Sustainable Energy Reviews*, *38*, 1003-1014.

27. Ozuomba Simeon , S.T Wara, C. Kalu and S.O Oboma (2006) ; *Computer Aided design of the magnetic circuit of a three phase power transformer, Ife Journal of Technology Vol.15, No. 2 , November 2006 , PP 99 – 108*

28. Eti-Ini Robson Akpan, Ozuomba Simeon, Sam Bassey Asuquo (2020). POWER FLOW ANALYSIS USING INTERLINE POWER FLOW CONTROLLER *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 5, May – 2020*

29. Ajayi, O. O. (2010). The potential for wind energy in Nigeria. *Wind engineering*, *34*(3), 303-311.

30. Kalu, C., Ezenugu, I. A. & Ozuomba, Simeon. (2015). Development of matlab-based software for peak load estimation and forecasting: a case study of faculty of engineering, Imo State University Owerri, Imo state, Nigeria. *European Journal of Engineering and Technology*, *3 (8)*, 20-29.

31. Effiong, Clement, Ozuomba Simeon, and Fina Otosi Faithpraise (2020). "Modelling And Forecasting Peak Load Demand In Uyo Metropolis Using Artificial Neural Network Technique." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 3, March – 2020*

32. Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: the way forward. *Energy, Sustainability and Society*, *2*(1), 1-17.

33. Effiong, Clement, Simeon Ozuomba, and Udeme John Edet (2016). Long-Term Peak Load Estimate and Forecast: A Case Study of Uyo Transmission Substation, Akwa Ibom State, Nigeria. *Science Journal of Energy Engineering 4(6), 85-89.*

34. Oyedepo, S. O. (2014). Towards achieving energy for sustainable development in Nigeria. *Renewable and sustainable energy reviews*, *34*, 255-272.

35. Stephen, Bliss Utibe-Abasi, Ozuomba Simeon, and Sam Bassey Asuquo. (2018) "Statistical Modeling Of The Yearly Residential Energy Demand In Nigeria." *Journal of Multidisciplinary Engineering Science Studies* (JMESS) Vol. 4 Issue 6, June – 2018

36. Emodi, N. V., & Boo, K. J. (2015). Sustainable energy development in Nigeria: Current status and policy options. *Renewable and Sustainable Energy Reviews*, *51*, 356-381.

37. Uko, Sampson Sampson, Ozuomba Simeon, and Ikpe Joseph Daniel (2019). Adaptive neuro-fuzzy inference system (ANFIS) model for forecasting and predicting industrial electricity consumption in Nigeria. *Advances in Energy and Power*, 6(3), 23-36.

38. Ozuomba, Simeon, Victor Akpaiya Udom & Jude Ibanga. (2018). Iterative Newton-Raphson-Based Impedance Method For Fault Distance Detection On Transmission Line. Education, 2020. *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 5, May - 2020*

39. Nerini, F. F., Broad, O., Mentis, D., Welsch, M., Bazilian, M., & Howells, M. (2016). A cost

comparison of technology approaches for improving access to electricity services. *Energy*, *95*, 255-265.

40. Oseni, M. O. (2012). Improving households' access to electricity and energy consumption pattern in Nigeria: Renewable energy alternative. *Renewable and Sustainable Energy Reviews*, *16*(6), 3967-3974.
41. Aliyu, A. S., Dada, J. O., & Adam, I. K. (2015). Current status and future prospects of renewable energy in Nigeria. *Renewable and sustainable energy reviews*, *48*, 336-346.
42. Aliyu, A. S., Dada, J. O., & Adam, I. K. (2015). Current status and future prospects of renewable energy in Nigeria. *Renewable and sustainable energy reviews*, *48*, 336-346.
43. Aliyu, A. K., Modu, B., & Tan, C. W. (2018). A review of renewable energy development in Africa: A focus in South Africa, Egypt and Nigeria. *Renewable and Sustainable Energy Reviews*, *81*, 2502-2518.
44. Anang, N., Azman, S. S. N., Muda, W. M. W., Dagang, A. N., & Daud, M. Z. (2021). Performance analysis of a grid-connected rooftop solar PV system in Kuala Terengganu, Malaysia. *Energy and Buildings*, *248*, 111182.
45. Ayompe, L. M., Duffy, A., McCormack, S. J., & Conlon, M. (2011). Measured performance of a 1.72 kW rooftop grid connected photovoltaic system in Ireland. *Energy conversion and management*, *52*(2), 816-825.
46. Dondariya, C., Porwal, D., Awasthi, A., Shukla, A. K., Sudhakar, K., SR, M. M., & Bhimte, A. (2018). Performance simulation of grid-co
47. Harahap, P., Pasaribu, F. I., Siregar, C. A. P., & Oktrialdi, B. (2021). Performance of Grid-Connected Rooftop Solar PV System for Households during Covid-19 Pandemic. *Journal of Electrical Technology UMY*, *5*(1), 26-31.
48. Okundamiya, M. S., Akpaida, V. O., & Omatahunde, B. E. (2014). Optimization of a hybrid energy system for reliable operation of automated teller machines. *Journal of Emerging Trends in Engineering and Applied Sciences*, *5*(8), 153-158.
49. Karthikeyan, S., Prakash, P. K., Krishna, K. L., & Poovarasan, V. (2021, March). Review on Powering an Automated Teller Machine using Vertical Axis Wind Turbine and Solar Energy. In *2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)* (pp. 1637-1640). IEEE.
50. Genevois, M. E., Celik, D., & Ulukan, H. Z. (2015). ATM location problem and cash management in automated teller machines. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, *9*(7), 2543-2548.
51. Yaqub, J. O., Bello, H. T., Adenuga, I. A., & Ogundeji, M. O. (2013). The cashless policy in Nigeria: prospects and challenges. *International Journal of Humanities and Social Science*, *3*(3), 200-212.
52. Ovat, O. O. (2012). The Central Bank of Nigeria's cashless policy in Nigeria: Benefits and challenges. *Journal of Economics and Sustainable Development*, *3*(14).