Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 5 Issue 12, December - 2021

Sizing Of Off-Grid Photovoltaic Power System For Internet Café And Portable Device Charging Station

Steve Worgu[1]
Department of Electrical/ Computer Engineering, Port Harcourt Polytechnic, Rumuola, Port Harcourt Nigeria

Wali Samuel[2]
Department of Electrical/Electronic and Computer Engineering, University of Uyo, Akwa Ibom, Nigeria

***Abstract*— In this paper, sizing of off-grid photovoltaic power system for internet café and portable device charging station is presented. First, the load demand profile of the internet café and portable device charging station was determined. Next, the geo-coordinates of the internet café was used to download the solar radiation data for the sizing computation. The actual sizing operation was performed using PVSyst software. The PVSyst was used to model the hourly distribution of the load, as well as the configuration of the PV array and the battery bank. The simulation results showed that there are 24 pieces of 250 Wp photovoltaic (PV) modules in the PV array which occupied a total area of 39 m^2 and gave a total output power of 5.31 kWp. The battery bank consisted of 112 batteries (with 4 batteries in series and 28 battery strings in parallel) and the battery has a total capacity of 2800 Ah at nominal battery voltage of 48V. The average yearly energy output available from the PV array is 6.97 MWh/year, the energy used by the load is 5.74 MWh/year, missing energy (energy demanded but not supplied) is 0.15 MWh/year, the annual user load demand is 5.884 MWh/year) and a solar fraction of 97.52% . Furthermore, the system has a performance ratio of 63.0%. In essence, about 37 % of the energy generated from the PV array are lost.**

Keywords: PVSyst Software, Sizing Of Solar Power System, Optimal Tilt Angle, Off-Grid Power System, Photovoltaic Power, Loss Diagram

1. INTRODUCTION

In recent years, there is increasing adoption of information and communication technologies (ICT) in the remote parts of developing countries and this has necessitated the provision of access to internet for people in such areas [1,2,3,4,5,6,7,8]. Also, the use of portable smart phones and smart devices to perform most of the ICT operations and also access the internet has also prompted the provision of both internet access hotspots and wireless network base stations in remote areas [9,10,11].

Particularly, in Nigeria, people living in most of the rural communities across the nation suffer both lack of access to electric power supply and lack of internet service [12,13,14,15,16,17,18,19]. In some cases, the cellular network services are available but with weak signals that frustrate the users. In such cases, some organizations and business experts setup solar-powered internet café' and mobile device charging stations to serve the rural communities that are cutoff from the national grid and mainstream internet services.

Notably, the solar power has been adjudged to be the best alternative energy supply because it is environmentally friendly and also it is increasingly becoming affordable in view of the steady decrease in the setup and running costs of the photovoltaic solar power supply components [20,21,22,23,24,25,26,27,28]. Importantly, in order to meet the desired energy demand, the solar power components must be properly selected in terms of their capacities to accommodate the variations in the solar radiation and the need to meet the power demand irrespective of such variations [29,30,31,32,33]. Accordingly, in this paper, the sizing of the solar power supply system for a case study internet café and portable device charging station is presented. The sizing operation is carried out using PVSyst software.

2 METHODOLOGY

2.1 The Load Demand and Meteorological Data

The approached used in the sizing of the off-grid photovoltaic power system includes determination of the daily load demand profile, acquisition of meteorological data of the installation site, sizing of the PV array, the battery band as well as sizing of the inverter and charger controller. The daily load demand profile is obtained and presented in Table 1. The Google map showing the location of the case study PV power installation site near Swali Market in Yenagoa Bayelsa State at coordinates (of 4.918729, 6.267808) with latitude of 4.918729 and longitude of 6.267808, as shown in Figure 1. The load profile of the case study as modelled in the PVSyst software is shown in Figure 2 while Figure 3 shows the hourly distribution of the case study load as modelled in the PVSyst software.

Table 1: The Internet café and portable device charging station daily load demand profile

S/N	Appliance	Rated Power (W)	Quantity	Total Power (kW)	Hours per day (h)	Energy Per Day (kWh/day)
1	Laptop Computer	65	20	1.3	10	13
2	TranzeoWiFi radio	6	2	0.012	10	0.12
3	Cell phone charger	5	20	0.1	10	1
4	Digital Camera battery charger	6	10	0.06	10	0.6
5	Photo Printer for Digital Camera	10	10	0.1	10	1
6	DC Fan for the WiFi radio	25	2	0.05	10	0.5
		Total	64	1.622		16.12

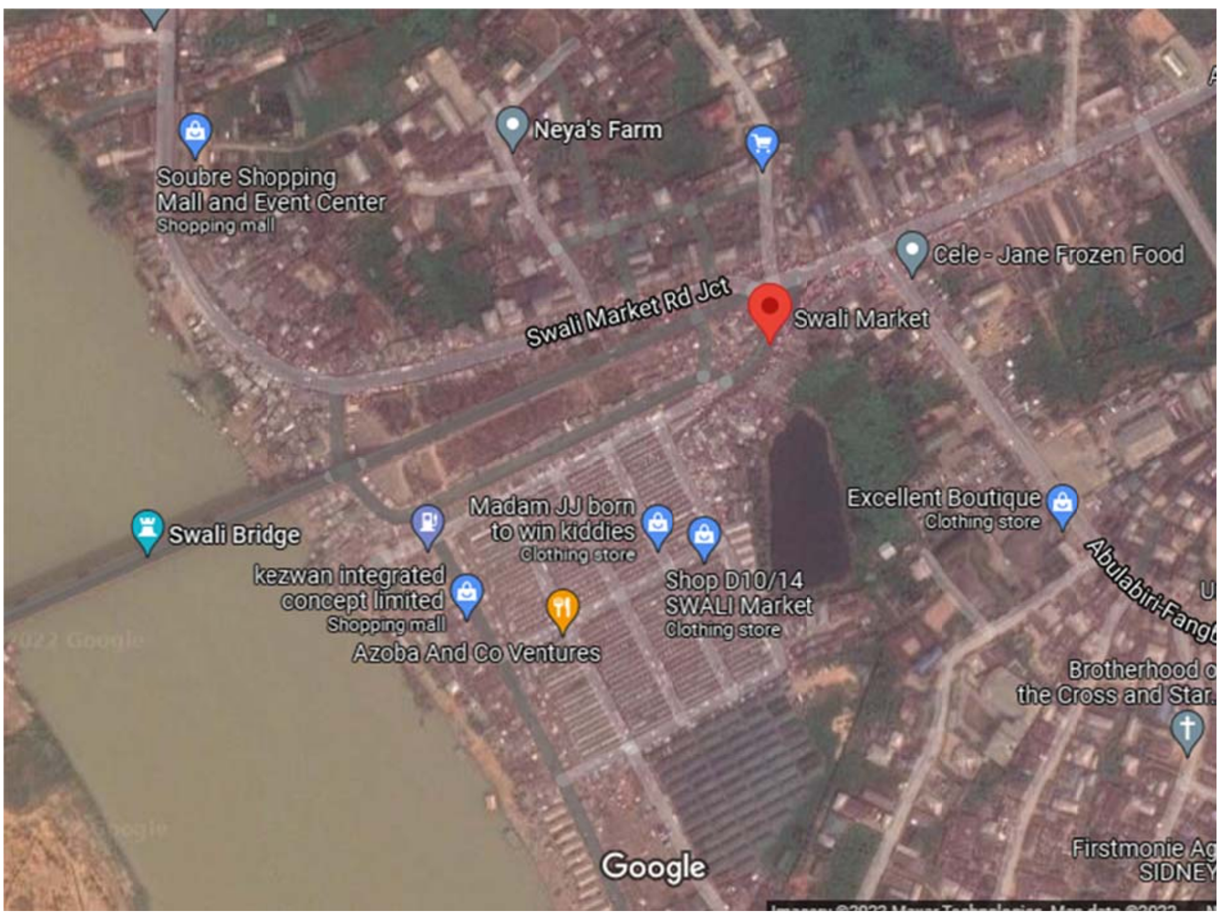


Figure 1 The Google map showing the location of the PV power installation site near Swali Market in Yenagoa Bayelsa State at coordinates of latitude of 4.918729 and longitude of 6.267808

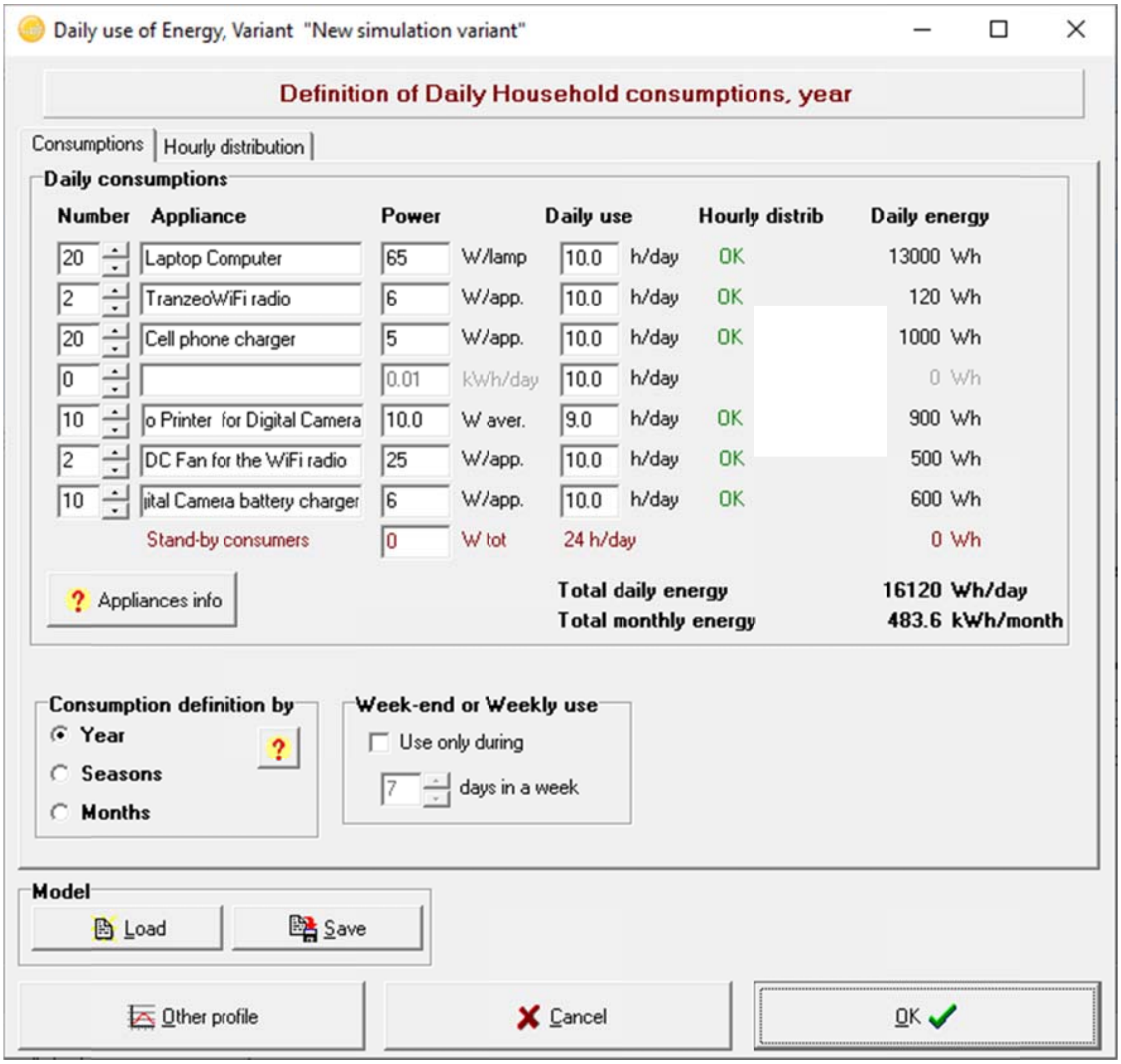


Figure 2 The load profile of the case study as modelled in the PVSyst software

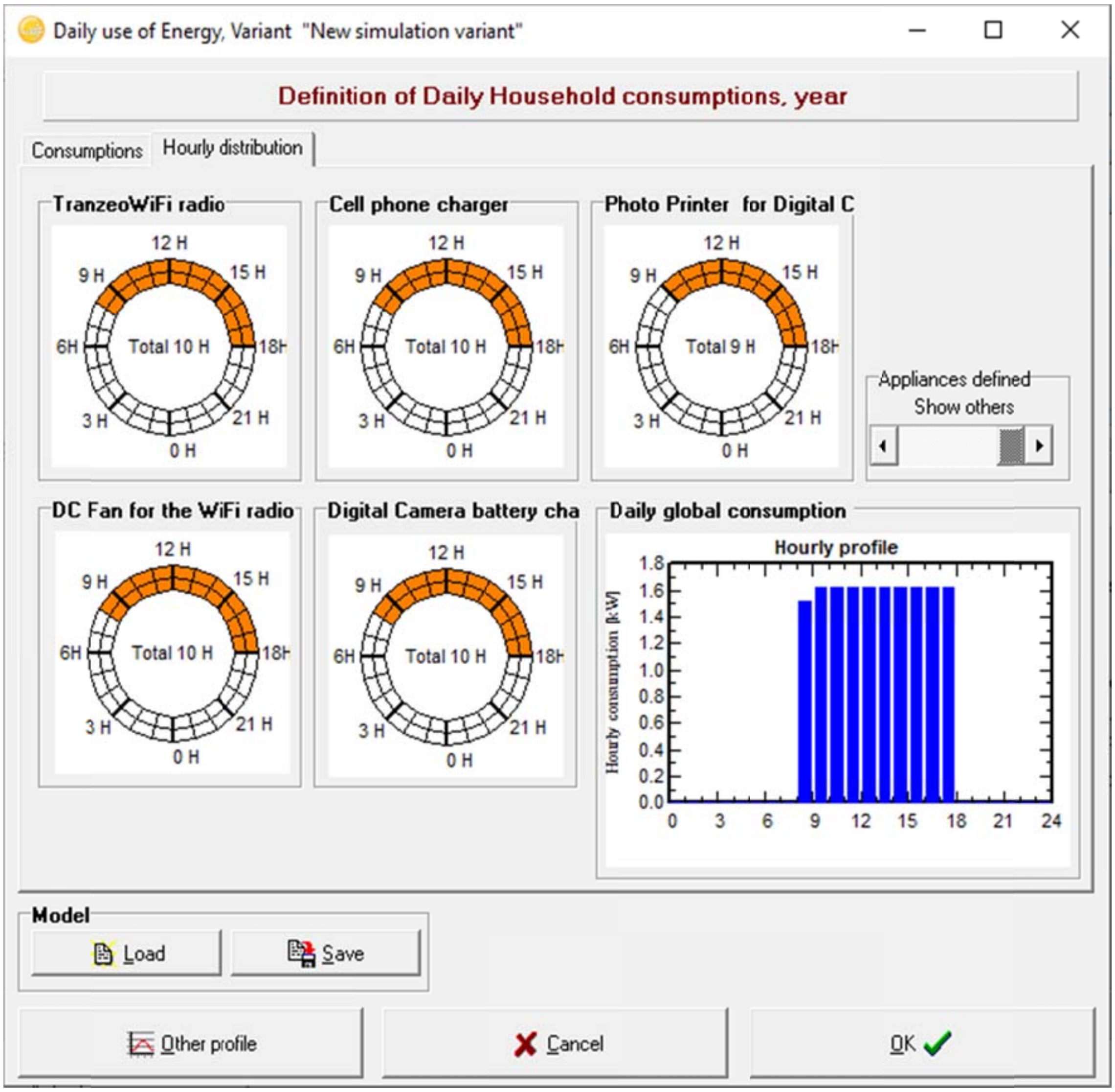


Figure 3 The hourly distribution of the case study load as modelled in the PVSyst software

2.2 Sizing of the PV System Components

The PV array power output denoted as P_{PV} is computed from the daily energy demand (E_{PV}) to be supplied by the PV array, as;

The output power, P_{pva} of the PV array is determined as

$$P_{PV} = \frac{E_{PV}}{(\eta_i)(\eta_c)(f_{dl})(PSH)} \tag{1}$$

Where η_{PV} is the PV module efficiency, η_c is the efficiency of the charge controller, f_{dl} are total dirating factors (f_{dl} is about 0.88), PSH is the daily peak sunshine hours. Also, P_{PV} is related to A_{tm} (that is the required total area of the PV array) as follows;

$$P_{PV} = \eta_{PV}(S_r)(A_{tm}) \tag{2}$$

where S_r denotes the solar radiation on the plane of the PV module and η_{PV} is the PV module efficiency which is given as;

$$\eta_{PV} = \eta_{PVSTC}\left[1 + K\left(T_{op} - 25\,°C\right)\right] \tag{3}$$

Where: η_{PVSTC} denotes the standard test condition module efficiency under, K denotes the cell temperature coefficient for the PV module, T_{op} denotes the operating cell temperature the PV module. Let the area for one PV module be denoted as A_m and N_{PV} denote the number of PV modules in the PV array, then;

$$A_{tm} = (A_m)N_{PV} = \frac{P_{PV}}{\eta_{PV}(S_r)} \tag{4}$$

Hence,

$$N_{PV} = \frac{P_{PV}}{\eta_{PV}(S_r)(A_m)} \tag{5}$$

Let N_{SPV} denote the number of PV modules that are connected in series, N_{PVP} denote the number of PV modules strings that are connected in parallel, the PV module nominal voltage be denoted as V_{PV} and the system line voltage be denoted as V_{SYS} , then;

$$N_{SPV} = \frac{V_{SYS}}{V_{PV}} \tag{6}$$

$$N_{PVP} = \frac{N_{PV}}{N_{SPV}} \qquad (7)$$

Let N_{DA} denote the number of days of autonomy, DoD denote the depth of discharge, the individual battery nominal voltage be denoted as V_{bat} , f_{bat} is a parameter to account for battery self-discharge and other safety operating considerations (f_{bat} is about 0.85) and the total watt-hour per day which is daily load demand is denoted as $\mathrm{E_{PV}}$, then required Ampere-hour (Ah) battery capacity denoted $\mathrm{E_{bb}}$ as is given as;

$$\mathrm{E_{bb}} = \frac{\mathrm{E_{PV}}\,(N_{DA})}{f_{bat}\ \mathrm{x\ DoD\ x}\ V_{SYS}} \qquad (8)$$

Let the number of batteries in series be denoted as N_{Sbat} , the number of batteries in parallel be denoted as N_{pbat}, denote the Ampere-hour (Ah) capacity of each battery be denoted $\mathrm{C_{bat}}$ and the total number of batteries be denoted as N_{bat}, then;

$$N_{Sbat} = \frac{V_{SYS}}{V_{bat}} \qquad (9)$$

$$N_{bat} = \frac{\mathrm{E_{bb}}}{\mathrm{C_{bat}}} \qquad (10)$$

$$N_{pbat} = \frac{N_{pbat}}{N_{sbat}} \qquad (10)$$

The inverter is used to convert the DC power into AC power output and it operates at the same terminal voltage of the battery bank (which in this case is V_{SYS}). Usually, a safety factor, f_{INVsaf} is recommended to oversize the inverter above the load demand it will support, Hence, inverter capacity denoted as $\mathrm{C_{INV}}$ is given as;

$$\mathrm{C_{INV}} = \mathrm{P_{PV}}(1 + f_{INVsaf}) \qquad (11)$$

Where f_{INVsaf} is about 0.2 to 0.3.

The selection of the PV module , battery, charger controller and inverter for the solar power system is implemented using PVSyst , and the screenshot of the configuration of the system PV array, and battery bank is shown in Figure 4. The system configuration in Figure 4 was used in PVSyst software to simulate the solar power system operation

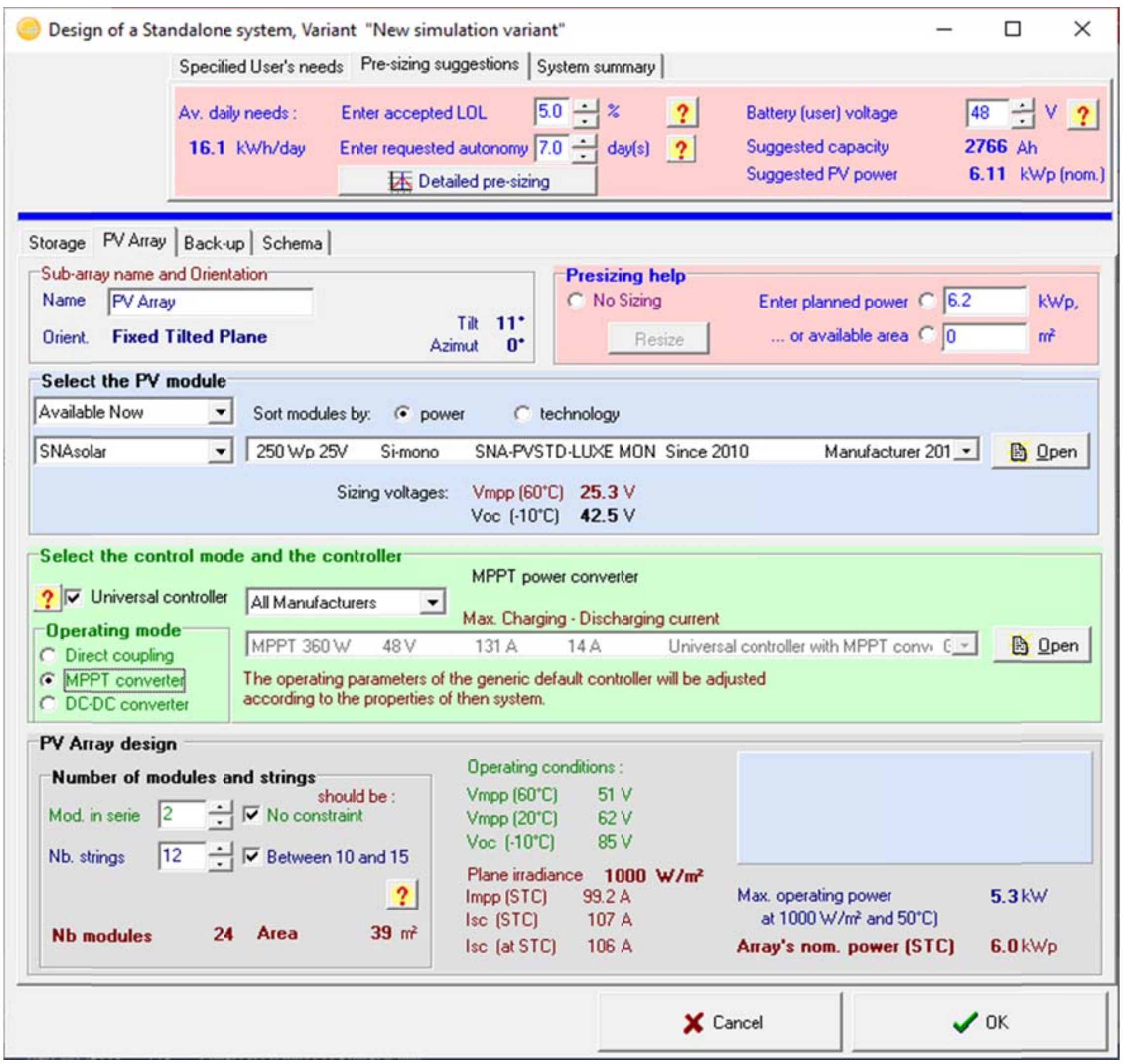


Figure 4 The screenshot of the PVSyst configuration of the PV array, battery bank, and charger controller for the solar power system

3. RESULTS AND DISCUSSION

The simulation parameters setting used in the PVSyst software , as shown in Figure 5 shows that there are 24 PV modules (each rates 250 Wp at STC) in the PV array which occupies a total area of 39 m^2 and a total operating power of 5.31 kWp at 50°C. The battery bank consists of 112 batteries (with 4 batteries in series and 28 battery strings in parallel) and the battery has a total capacity of 2800 Ah at nominal battery voltage of 48V. Also, the daily user needs or electric load demand (as captured in the PVSyst simulation parameters in Figure 6) shows that the daily energy demand is 16120 Wh/day.

The average yearly energy output available from the PV array is 6.97 MWh/year, the energy used by the load is 5.74 MWh/year, missing energy (energy demanded but not supplied) is 0.15 MWh/year . The annual user load demand (in Figure 6) is 5.884 MWh/year) and for with the 5.74 MWh/year energy delivered to the load per year, the solar fraction is computed as (5.74*100%)/5.884) which amounts to a solar fraction of 97.52% (as shown in Figure 7). Furthermore, the system has a performance ratio of 63.0%. In essence, about 37 % of the energy generated from the PV array are lost , as shown in the loss diagram of Figure 8.

The simulation parameters setting used in the PVSyst software z

PVSYST V6.70		18/03/22	Page 1/4

Stand Alone System: Simulation parameters

Project : **Internet Cafe Sizing**

Geographical Site	**BAYELSA STATE**		Country	**Nigeria**
Situation	Latitude	4.79° N	Longitude	6.32° E
Time defined as	Legal Time	Time zone UT	Altitude	62 m
	Albedo	0.20		
Meteo data:	**BAYELSA STATE**	NASA-SSE satellite data, 1983-2005 - Synthetic		

Simulation variant : **New simulation variant**

Simulation date 18/03/22 04h45

Simulation parameters	System type	**Stand-alone system**		
Collector Plane Orientation	Tilt	11°	Azimuth	0°
Models used	Transposition	Hay	Diffuse	Perez, Meteonorm

PV Array Characteristics

PV module	Si-mono	Model	**SNA-PVSTD-LUXE MONO 250**		
Original PVsyst database		Manufacturer	SNAsolar		
Number of PV modules		In series	2 modules	In parallel	12 strings
Total number of PV modules		Nb. modules	24	Unit Nom. Power	250 Wp
Array global power		Nominal (STC)	**6.00 kWp**	At operating cond.	5.31 kWp (50°C)
Array operating characteristics (50°C)		U mpp	54 V	I mpp	99 A
Total area		Module area	**39.0 m²**	Cell area	34.7 m²

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.	9.2 mOhm	Loss Fraction	1.5 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	1.2 % at STC
Module Quality Loss			Loss Fraction	1.5 %
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

System Parameter	System type	**Stand Alone System**		
Battery	Model	**Volta 6SB100**		
	Manufacturer	Volta		
Battery Pack Characteristics	Voltage	48 V	Nominal Capacity	2800 Ah
	Nb. of units	4 in series x 28 in parallel		
	Temperature	Fixed (20°C)		
Controller	Model	Universal controller with MPPT converter		
	Technology	MPPT converter	Temp coeff.	-5.0 mV/°C/elem.
Converter	Maxi and EURO efficiencies	97.0 / 95.0 %		
Battery Management control	Threshold commands as	SOC calculation		
	Charging	SOC = 0.90 / 0.75	i.e. approx.	52.6 / 50.1 V
	Discharging	SOC = 0.20 / 0.45	i.e. approx.	47.3 / 48.9 V
User's needs :	Daily household consumers	Constant over the year		
	average	16.1 kWh/Day		

Figure 5 The simulation parameters setting used in the PVSyst software

PVSYST V6.70		18/03/22	Page 2/4

Stand Alone System: Detailed User's needs

Project : **Internet Cafe Sizing**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Stand alone**		
PV Field Orientation	tilt	11°	azimuth	0°
PV modules	Model	SNA-PVSTD-LUXE MONO 250		250 Wp
PV Array	Nb. of modules	24	Pnom total	**6.00 kWp**
Battery	Model	Volta 6SB100	Technology	Lead-acid, sealed, tubular
Battery Pack	Nb. of units	112	Voltage / Capacity	**48 V / 2800 Ah**
User's needs	Daily household consumers	Constant over the year	Global	5884 kWh/year

Daily household consumers, Constant over the year, average = 16.1 kWh/day

Annual values

	Number	Power	Use	Energy
Laptop Computer	20	65 W/lamp	10 h/day	13000 Wh/day
TranzeoWiFi radio	2	6 W/app	10 h/day	120 Wh/day
Cell phone charger	20	5 W/app	10 h/day	1000 Wh/day
Photo Printer for Digital Camera	10		9 Wh/day	900 Wh/day
DC Fan for the WiFi radio	2	25 W tot	10 h/day	500 Wh/day
Digital Camera battery charger	10	6 W tot	10 h/day	600 Wh/day
Total daily energy				16120 Wh/day

Figure 6 The daily user needs or electric load demand

Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 5 Issue 12, December - 2021

PVSYST V6.70		18/03/22	Page 3/4

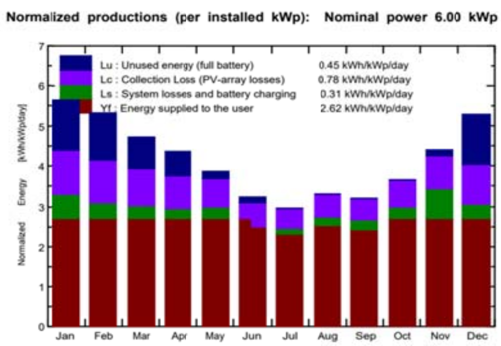
Stand Alone System: Main results

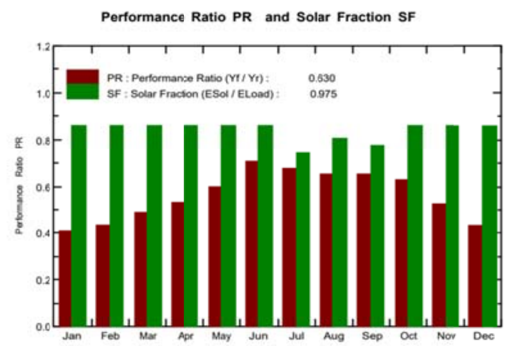
Project : **Internet Cafe Sizing**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Stand alone**		
PV Field Orientation	tilt	11°	azimuth	0°
PV modules	Model	SNA-PVSTD-LUXE MONO 250		250 Wp
PV Array	Nb. of modules	24	Pnom total	**6.00 kWp**
Battery	Model	Volta 6SB100	Technology	Lead-acid, sealed, tubular
Battery Pack	Nb. of units	112	Voltage / Capacity	**48 V / 2800 Ah**
User's needs	Daily household consumers	Constant over the year	Global	5884 kWh/year

Main simulation results				
System Production	**Available Energy**	**6.97 MWh/year**	Specific prod.	1162 kWh/kWp/year
	Used Energy	5.74 MWh/year	Excess (unused)	0.99 MWh/year
	Performance Ratio PR	63.00 %	Solar Fraction SF	97.52 %
Loss of Load	Time Fraction	2.5 %	Missing Energy	0.15 MWh/year





New simulation variant

Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E Avail MWh	EUnused MWh	E Miss MWh	E User MWh	E Load MWh	SolFrac
January	162.4	169.7	0.799	0.226	0.000	0.500	0.500	1.000
February	143.6	144.9	0.682	0.199	0.000	0.451	0.451	1.000
March	146.6	142.0	0.668	0.147	0.000	0.500	0.500	1.000
April	135.0	126.6	0.600	0.106	0.000	0.484	0.484	1.000
May	126.8	115.3	0.550	0.029	0.000	0.500	0.500	1.000
June	103.5	93.6	0.449	0.027	0.000	0.484	0.484	1.000
July	96.4	87.9	0.428	0.000	0.066	0.433	0.500	0.867
August	106.0	98.7	0.473	0.000	0.032	0.467	0.500	0.935
September	96.6	92.1	0.446	0.000	0.047	0.436	0.484	0.902
October	111.6	109.5	0.518	0.000	0.000	0.500	0.500	1.000
November	125.4	127.6	0.601	0.026	0.000	0.484	0.484	1.000
December	151.3	159.1	0.757	0.228	0.000	0.500	0.500	1.000
Year	1505.3	1467.0	6.972	0.989	0.146	5.738	5.884	0.975

Legends:				
	GlobHor	Horizontal global irradiation	E Miss	Missing energy
	GlobEff	Effective Global, corr. for IAM and shadings	E User	Energy supplied to the user
	E Avail	Available Solar Energy	E Load	Energy need of the user (Load)
	EUnused	Unused energy (full battery) loss	SolFrac	Solar fraction (EUsed / ELoad)

Figure 7 The main simulation results for the solar power system

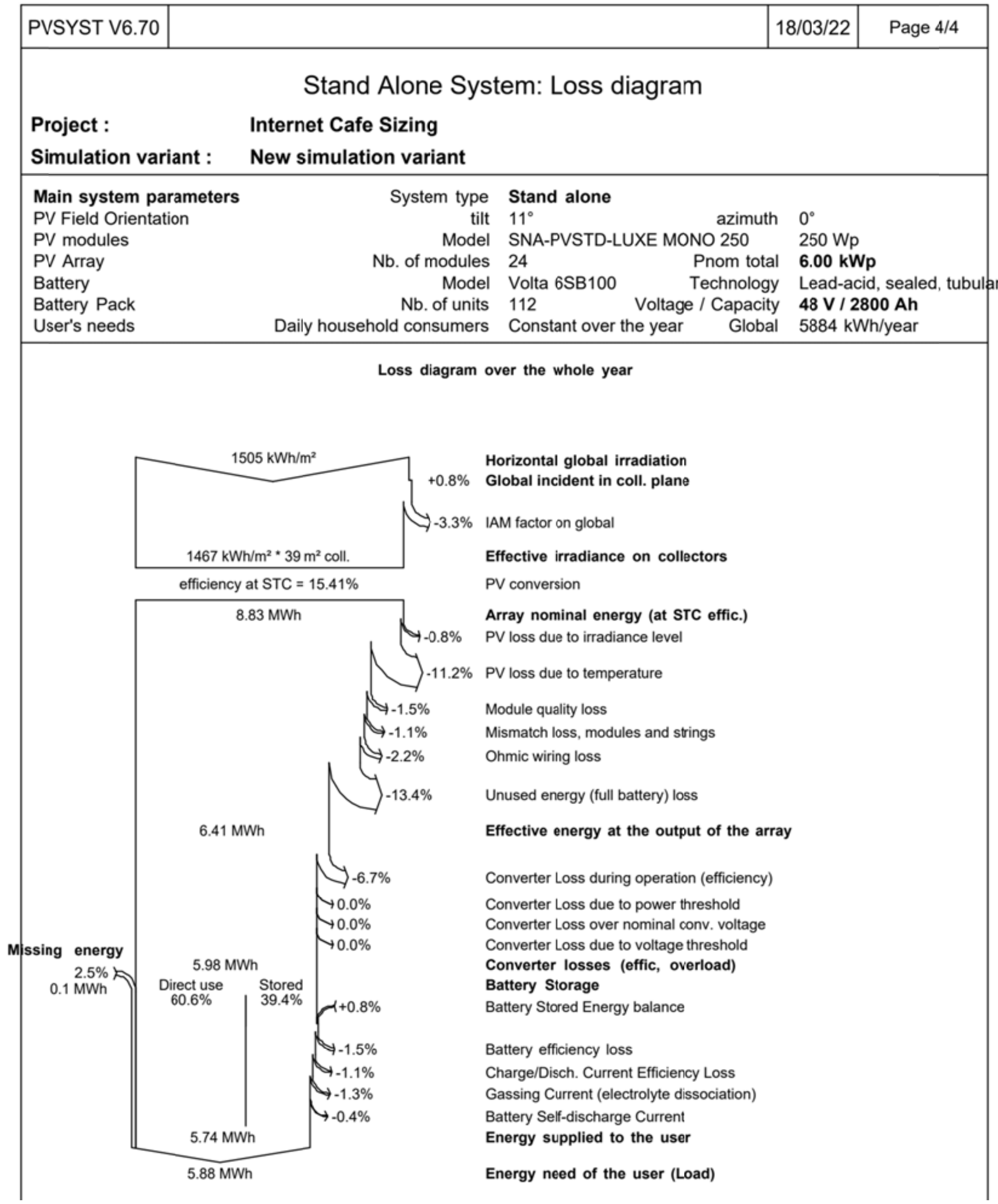


Figure 8 The loss diagram for the solar power system

4 CONCLUSION

The sizing of PV solar power using the load demand and solar radiation data of the case study for internet café and portable device charging station is presented. The component sizing operation was implemented using PVSyst simulation software which has features for modelling the load demand, the battery bank, the PV array and other components that make up the PV solar power system. The results show that on annual basis, the solar power system can satisfy the load demand of the case study internet café and portable device charging station in about 97.5 % of the time.

REFERENCES

1. El Bilali, H., & Allahyari, M. S. (2018). Transition towards sustainability in agriculture and food systems: Role of information and communication technologies. *Information Processing in Agriculture*, 5(4), 456-464.
2. Deichmann, U., Goyal, A., & Mishra, D. (2016). Will digital technologies transform agriculture in developing countries?. *Agricultural Economics*, *47*(S1), 21-33.
3. Singh, K. M., Kumar, A., & Singh, R. K. (2015). Role of information and communication technologies in Indian

agriculture: An overview. *Available at SSRN 2570710*.

4. Singh, K. M., Kumar, A., & Singh, R. K. (2015). Role of information and communication technologies in Indian agriculture: An overview. *Available at SSRN 2570710*.
5. Bali, S. (2018). Barriers to development of telemedicine in developing countries. In *Telehealth*. IntechOpen.
6. Tambotoh, J. J., Manuputty, A. D., & Banunaek, F. E. (2015). Socio-economics factors and information technology adoption in rural area. *Procedia Computer Science*, *72*, 178-185.
7. Aceto, G., Persico, V., & Pescapé, A. (2018). The role of Information and Communication Technologies in healthcare: taxonomies, perspectives, and challenges. *Journal of Network and Computer Applications*, *107*, 125-154.
8. Mittal, S., & Mehar, M. (2016). Socio-economic factors affecting adoption of modern information and communication technology by farmers in India: Analysis using multivariate probit model. *The Journal of Agricultural Education and Extension*, *22*(2), 199-212.
9. Abu-Sharkh, M. O. (2019, March). Performance Anomalies of Smartphone-based Mobile Wi-Fi Hotspots. In *2019 3rd International Conference on Recent Advances in Signal Processing, Telecommunications & Computing (SigTelCom)* (pp. 160-164). IEEE.
10. Ray, S. K., Sinha, R., & Ray, S. K. (2015, June). A smartphone-based post-disaster management mechanism using WiFi tethering. In *2015 IEEE 10th conference on industrial electronics and applications (ICIEA)* (pp. 966-971). IEEE.
11. Ogbonnaya, U. I., Awoniyi, F. C., & Matabane, M. E. (2020). Move to online learning during COVID-19 lockdown: Pre-service teachers' experiences in Ghana. *International Journal of Learning, Teaching and Educational Research*, *19*(10), 286-303.
12. Gift, R. A., Raimi, M. O., Owobi, O. E., Oluwakemi, R. M., Anu, B., & Funmilayo, A. A. (2020). Nigerians crying for availability of electricity and water: a key driver to life coping measures for deepening stay at home inclusion to slow covid-19 spread. *Gift RA, Olalekan RM, Owobi OE, Oluwakemi RM, Anu B, Funmilayo AA (2020). Nigerians crying for availability of electricity and water: a key driver to life coping measures for deepening stay at home inclusion to slow covid-19 spread. Open Access Journal of Science*, *4*(3), 69-80.
13. Adediran, Y. A., Opadiji, J. F., Faruk, N., & Olayiwola, W. B. (2016). On issues and challenges of rural telecommunications access in Nigeria.
14. 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*
15. Usah, E. O., Ozuomba, S., Oduobuk, E. J., & Ekott, E. E. 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)*, *5*, 11.
16. Markson, I., Ozuomba, S., & Abasi-Obot, I. E. (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.
17. Usah, E. O., Ozuomba, S., & Ekott, E. E. Design And Construction Of Circuits For An Integrated Solar-Wind Energy System With Remote Monitoring And Control Mechanism.
18. Simeon, O. Victor , A. U. and Sam B. A. (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
19. Usah, E. O., Ozuomba, S., & Ekott, E. E. 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*(5.808841), 4-53.
20. Vaka, M., Walvekar, R., Rasheed, A. K., & Khalid, M. (2020). A review on Malaysia's solar energy pathway towards carbon-neutral Malaysia beyond Covid'19 pandemic. *Journal of Cleaner Production*, *273*, 122834.
21. Bohra, S. S., Anvari-Moghaddam, A., & Mohammadi-Ivatloo, B. (2019, October). AHP-assisted multi-criteria decision-making model for planning of microgrids. In *IECON 2019-45th Annual Conference of the IEEE Industrial Electronics Society* (Vol. 1, pp. 4557-4562). IEEE.
22. Hu, X., Imran, M., Wu, M., Moon, H. C., & Liu, X. (2020). Alternative to Oil and Gas: Review of Economic Benefits and Potential of Wind Power in Pakistan. *Mathematical Problems in Engineering*, *2020*.
23. Archibong, E. I., Ozuomba, S., & Ekott, E. (2020, March). Internet of things (IoT)-based, solar powered street light system with anti-vandalisation mechanism. In *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)* (pp. 1-6). IEEE.
24. Usah, E. O., Ozuomba, S., Oduobuk, E. J., & Ekott, E. E. (2020). Development Of Analytical Model For Characterizing A 2500 W

Wind Turbine Power Plant Under Varying Climate Conditions In Nigeria. *Development*, *4*(6).

25. Simeon, O., Constance, K., & Essang, O. S. (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. *Assessment*, *5*(9).
26. Archibong, E. I., Ozuomba, S., & Ekott, E. E. (2020). Life Cycle Cost And Carbon Credit Analysis For Solar Photovoltaic Powered Internet Of Things-Based Smart Street Light In Uyo. *Life*, *5*(1).
27. Umoette, A. T., Ozuomba, S., & 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.
28. Deele, L. B., Ozuomba, S., & Essang, O. S. 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
29. Blanford, G. J., Merrick, J. H., Bistline, J. E., & Young, D. T. (2018). Simulating annual variation in load, wind, and solar by representative hour selection. *The Energy Journal*, *39*(3).
30. Elkadeem, M. R., Wang, S., Sharshir, S. W., & Atia, E. G. (2019). Feasibility analysis and techno-economic design of grid-isolated hybrid renewable energy system for electrification of agriculture and irrigation area: A case study in Dongola, Sudan. *Energy Conversion and Management*, *196*, 1453-1478.
31. Lau, K. Y., Muhamad, N. A., Arief, Y. Z., Tan, C. W., & Yatim, A. H. M. (2016). Grid-connected photovoltaic systems for Malaysian residential sector: Effects of component costs, feed-in tariffs, and carbon taxes. *Energy*, *102*, 65-82.
32. Deele, L. B., Ozuomba, S., & 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.
33. Simeon, O., Abasi-Obot, I. E., & Markson, I. (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.