International Multilingual Journal of Science and Technology (IMJST)
ISSN: 2528-9810
Vol. 7 Issue 1, January - 2022

Simulated Loss Of Load Analysis Of Off-Grid Solar Photovoltaic Solar Power Installation For Computer Laboratory In Akwa Ibom State

Sifon J. Umoh[1]
Department Of Electrical/Electronic and Computer Engineering, University of Uyo, Akwa Ibom State Nigeria

Oyadinrin Kayode Julius[2]
Department Of Electrical/Electronic and Computer Engineering, University of Uyo, Akwa Ibom State Nigeria

Abasi-obot, Iniobong Edifon[3]
Department of Electrical and Electronic Engineering, Akwa Ibom State University, Ikot Akpaden, Nigeria

Abstract— **In this paper, simulated loss of load analysis of off-grid Photovoltaic (PV) solar power installation for computer laboratory in Akwa Ibom State is presented. The case study computer laboratory has about 20 computer systems and a total daily energy demand of 53,046 Wh/day. The meteorological data was downloaded from NASA portal through PVSyst meteo-data import dialogue window using the installation site latitude of 5.05° and longitude of 7.90°. The results of the simulation conducted using PVSyst software showed that the standard test condition (STC) energy yield is 34.08MWh, the actual energy yield at the operating condition is 25.67 MWh while other losses including inverter, wire and battery losses reduced the energy delivered to the load to a value of 23.067 MWh. Also, the loss of load occurred in the months of July, September and October with an annual value of 1.44 % which is less than the maximum allowed value of 3% based on the system design specification. The simulation results also included the specific days and time of the day and the duration of the loss of load. Such detail information are relevant for power management planning.**

Keywords — Off-Grid , Loss Of Load , Photovoltaic Solar Power, Energy Demand, PVSyst Software

1. Introduction

Across the globe, laboratory practical has been accepted as essential for effective learning of theoretical concepts by engaging the students in hands-on implementation of the practical aspects of the course contents [1,2,3,4,5,6,7,8]. In this regard, computer laboratory is usually equipped with sufficient computer systems and other accessories and peripherals. Effective operation of computer laboratory therefore relies among other things on the provision of power supply to the laboratory. However, in Nigeria, uncertainty about power supply has made it difficult to effectively run computer laboratories in many institutions across the nation [9,10,11,12,13,14,15,16,17,18,19]. Moreover, many parts of Nigeria has no access to the national power grid. As such, some institution rely on diesel generators as alternative power source while some other institutions have adopted the solar power system [20,21,22,23,24,25,26,27,28]. Solar power has been advocated because it is less handful to the environment and cost of installation and maintenance of the solar power system have continued to drop over the years [29,30,31,32,33]. However, the challenge with solar power system is the irregularity in the availability of adequate solar radiation to meet the power demand of the load [34,35,36,37]. In this wise, there is in some cases loss of load which can hinder smooth operation of the computer laboratory [38,39,40,41].

Consequently, this paper considered a solar photovoltaic power system for a computer laboratory and analysed the loss of load probability based on the load demand of the computer laboratory and the solar radiation data of the site. Particularly, the simulated loss of load analysis of the case study computer laboratory was conducted using PVSyst software. The PVSyst software is download the required solar radiation data from NASA portal. The simulation is performed for an off-grid solar power system and the simulation results were discussed along with their implications.

2. METHODOLOGY

2.1 The Load Demand of the Computer Laboratory and the meteorological data and PV Array Orientation

The load demand of the computer laboratory is given in Table1. The laboratory has about 20 computer systems and a total daily energy demand of 53,046 Wh/day. The meteorological data was downloaded from NASA portal through PVSyst meteo-data import dialogue window using the installation site latitude of 5.05° and longitude of 7.90°, as shown in Figure 1. The PVSyst graph plot of the daily global irradiation on the horizontal plane and on the tilted plane of the PV module for the installation site is shown in Figure 2. The optimal tilt angle of 8° was selected using the PVSyst panel orintation dialogue box , shown in Figure 3. At the optimal angle , a transpotion factor of 1.01 was achieved which means that 1% of additional solar irradiation is collected by tilting the PV panel at 8° to the horizontal plane.

Table1. The load demand profile of the computer laboratory

S/N	Electrical Load Description	Power Rating (w)	Quantity	Number of Hours of operation per day	Power Demand Per Day (w)	Energy Demand Per Day (wh/day)
1	Computer System	120	20	10	2400	24000
2	Air conditioner	1200	2	10	2400	24000
3	Light	22	10	10	220	2200
4	Fan	67	4	10	268	2680
5	Printers	83	1	2	83	166
	Total				5371	53046

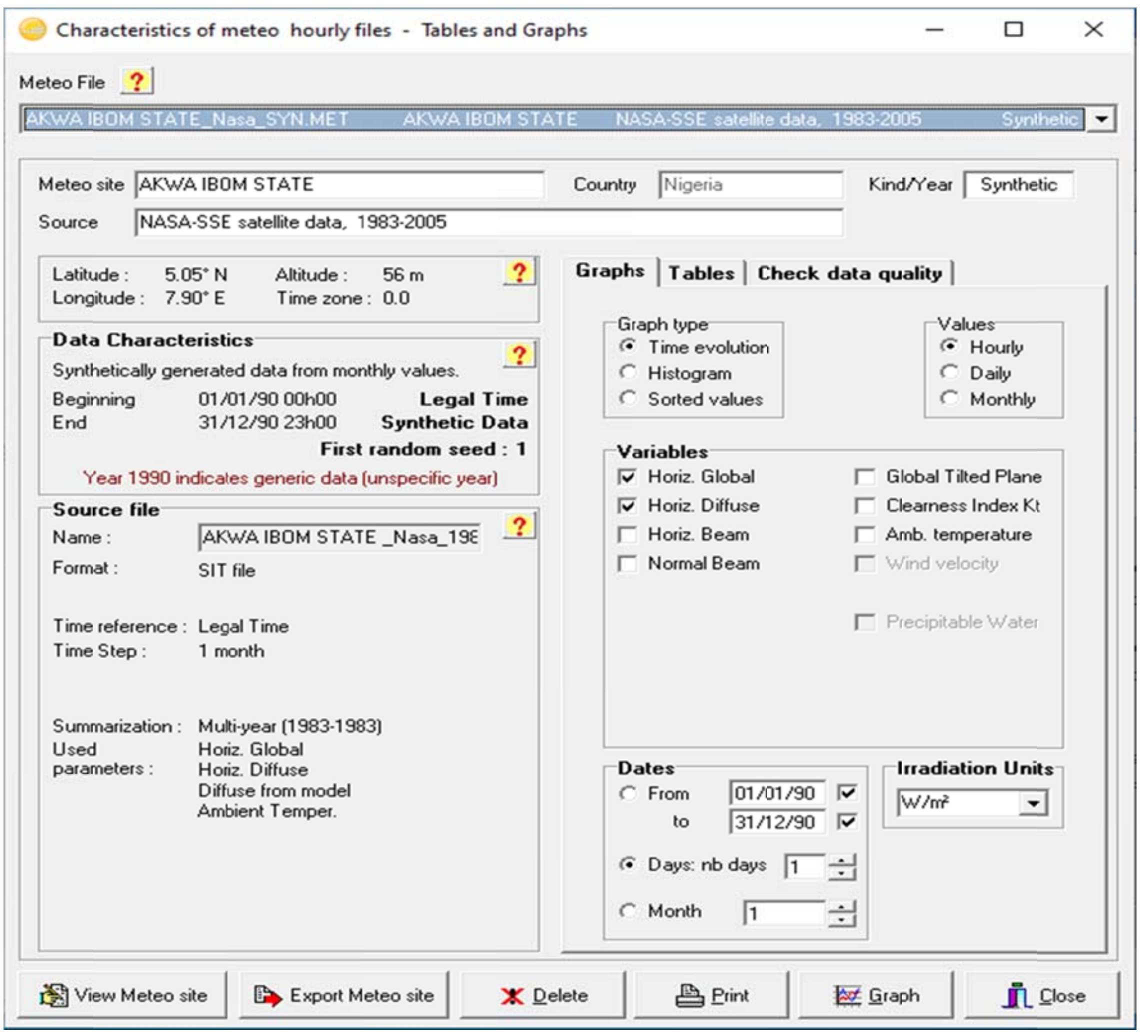

Figure 1. The PVSyst meteo-data dialogue window for the installation site with latitude of 5.05° and longitude of 7.90°,

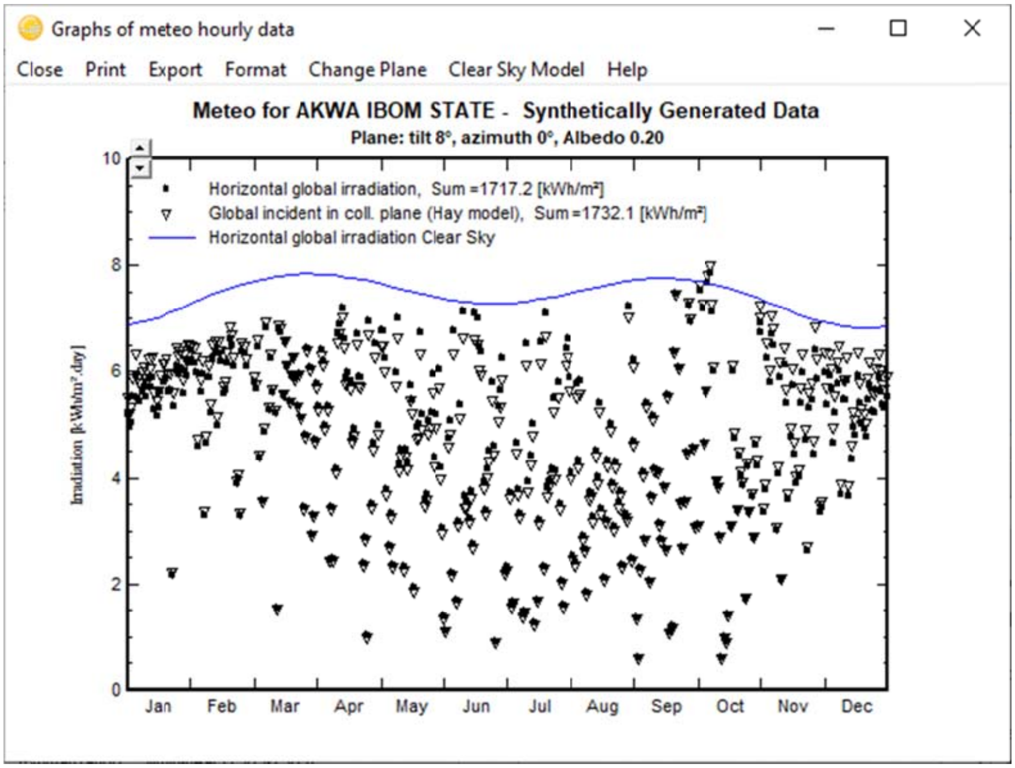

Figure 2. The PVSyst graph plot of the daily global irradiation on the horizontal plane and on the tilted plane of the PV module for the installation site

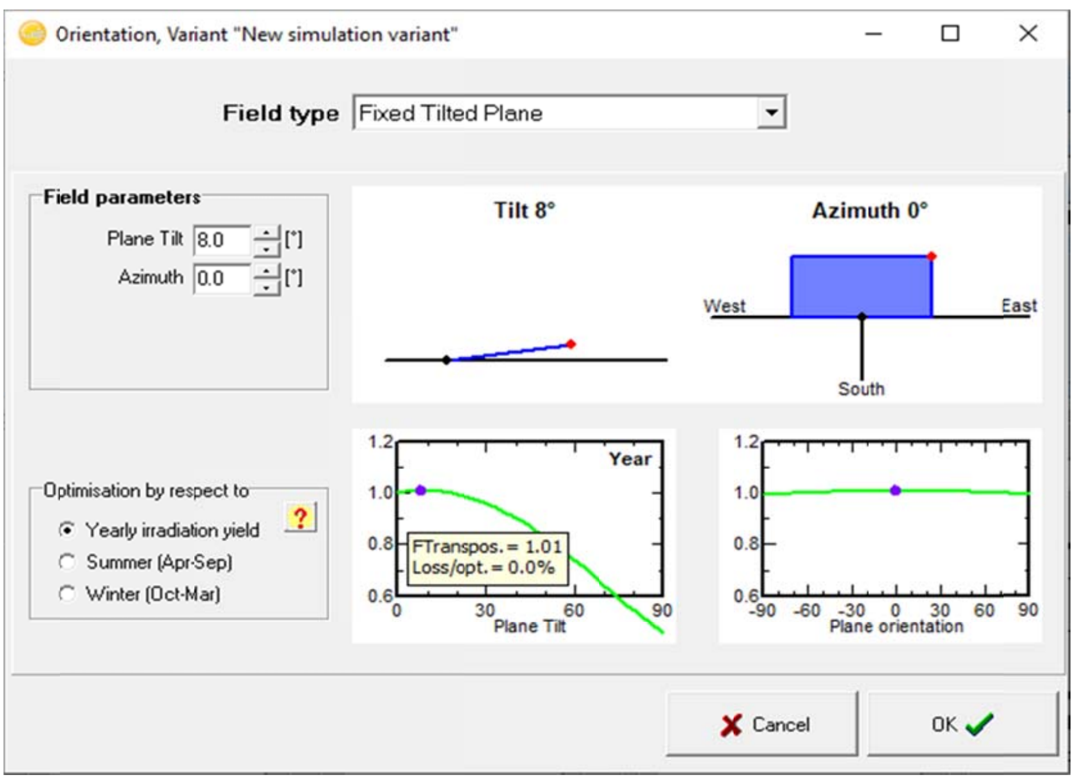

Figure 3. The PVSyst panel orintation dialogue box showing optimal tilt angle of 8° for the site

2.2 The PV Installation Model, Battery Bank, PV Array and System Configuration Settings using PVSyst Software

The layout of the off-grid system, as modelled in PVSyst program is shown in Figure 4. The specification of the battery used in the battery bank is presented in Figure 5 while the graph of the battery capacity versus discharge rate is shown in Figure 6. The battery is a 12 V, 150 Ah lead-acid battery manufactrerd by Electrona with model name of DuraSC. In all, the battery bank consist of 120 battery units with 8 batteries in series and 15 battery strings in parallel.

The specification of the PV module used in the PV array is presented in Figure 7 while current versus votage graph for the PV module depicting the module behaviour according to incident irradiation. is shown in Figure 8. The PV is a 48 V 100 Wp PV panel manufactrerd by Hullk Energy Technology with model name of CdF1000A1. In all, the PVarray , as shown in Figure 9 consist of 122 PV panel units with 2 PV panel in series and 101 PV strings in parallel. The infoemation in Figure 9 also shows that the 3 days of autonomy was selected along with maximum allowable loss of load probability of 4 %.

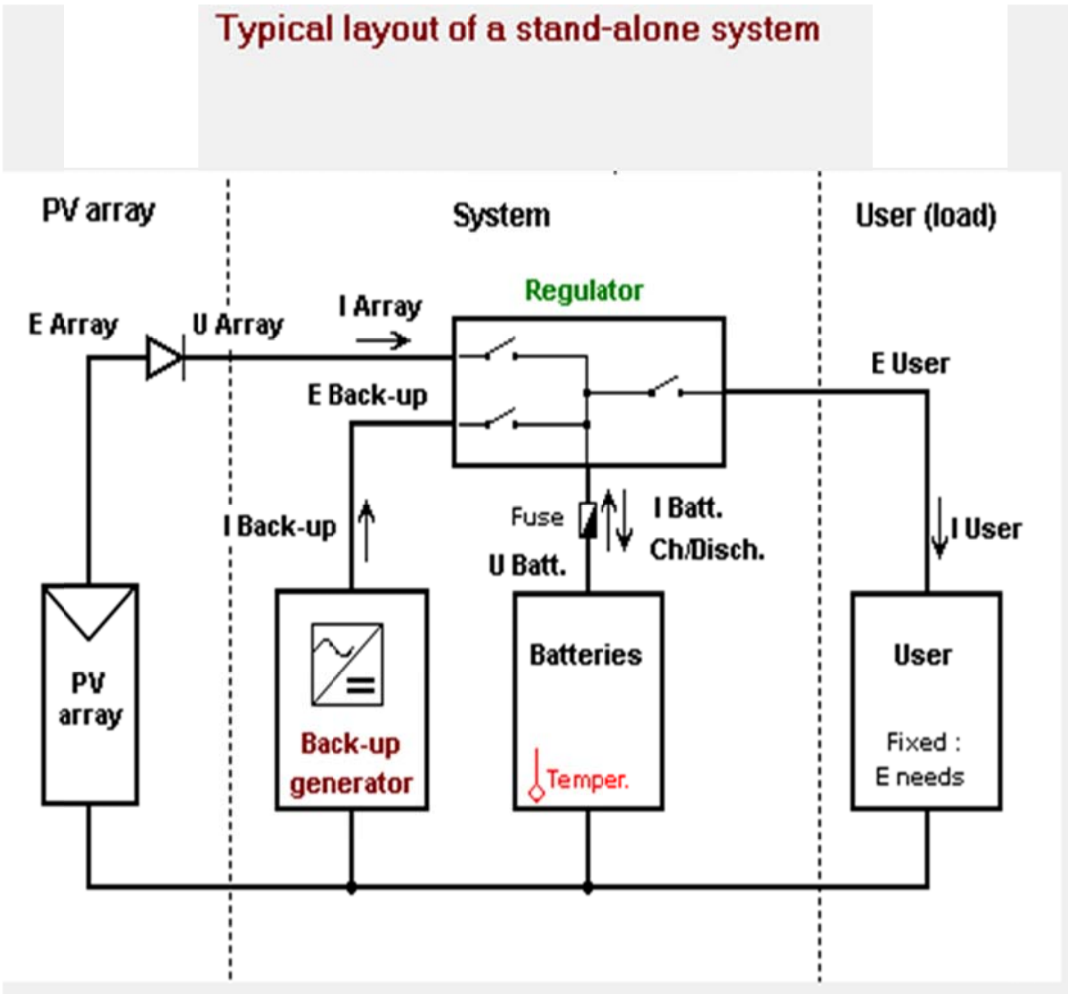

Figure 4 The layout of the off-grid system, as modelled in PVSyst program

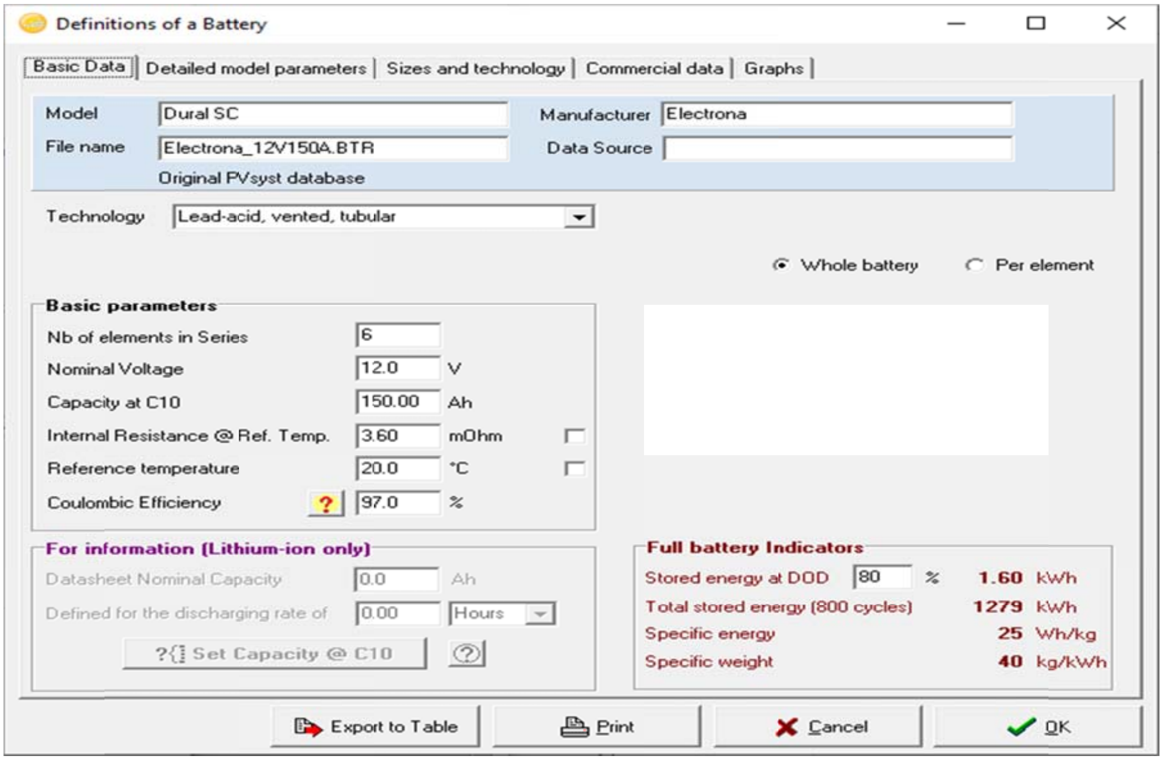

Figure 5 The specification of the battery used in the battery bank

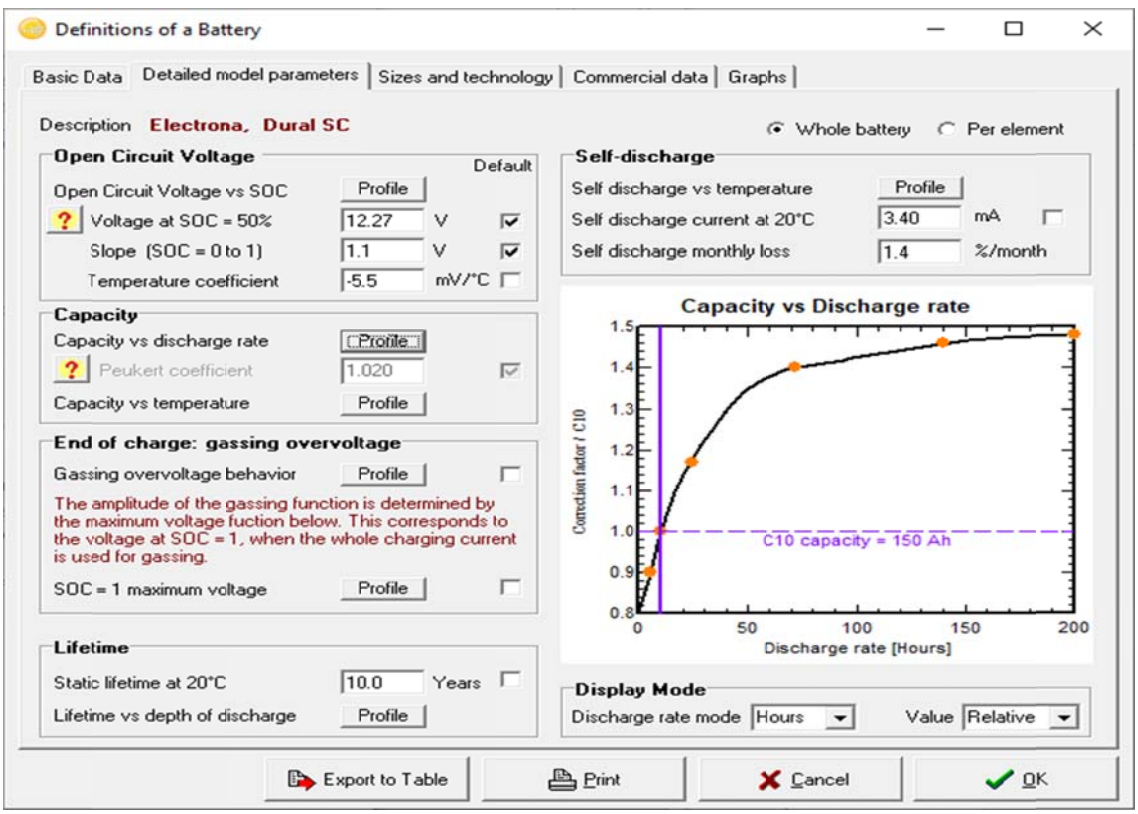

Figure 6 The graph of the battery capacity versus discharge rate

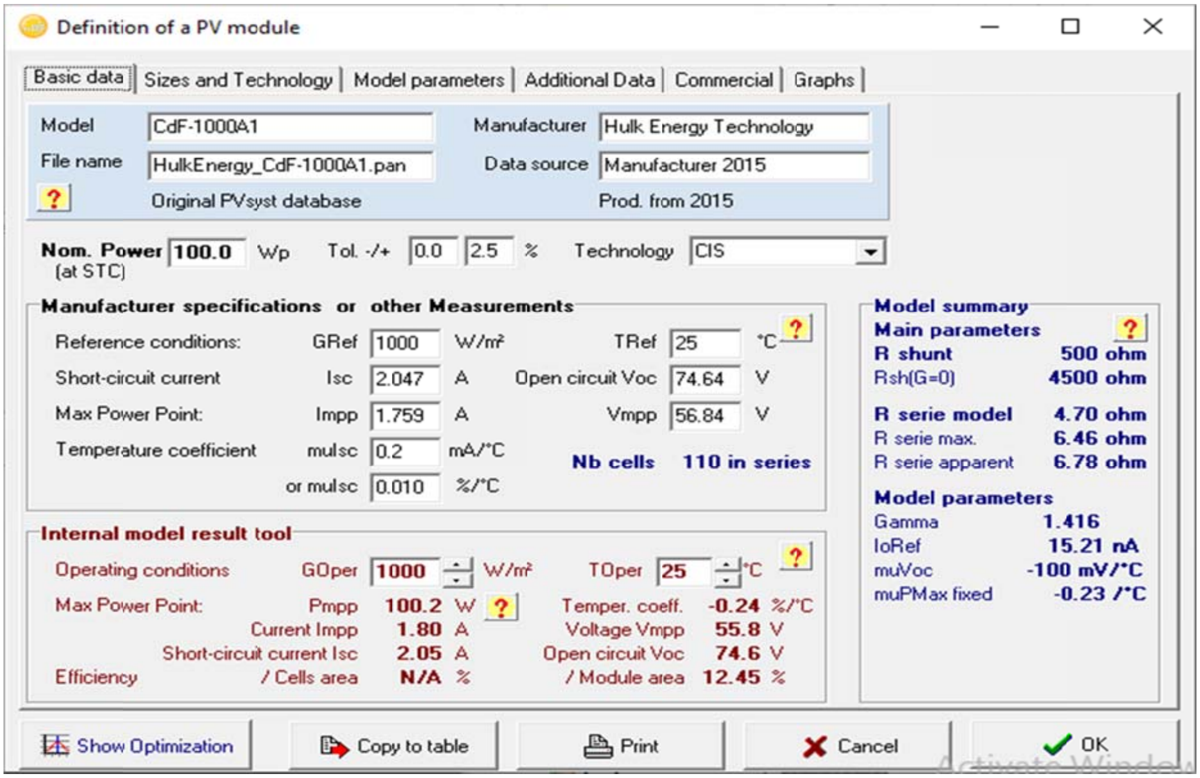

Figure 7 The specification of the PV module used in the PV array

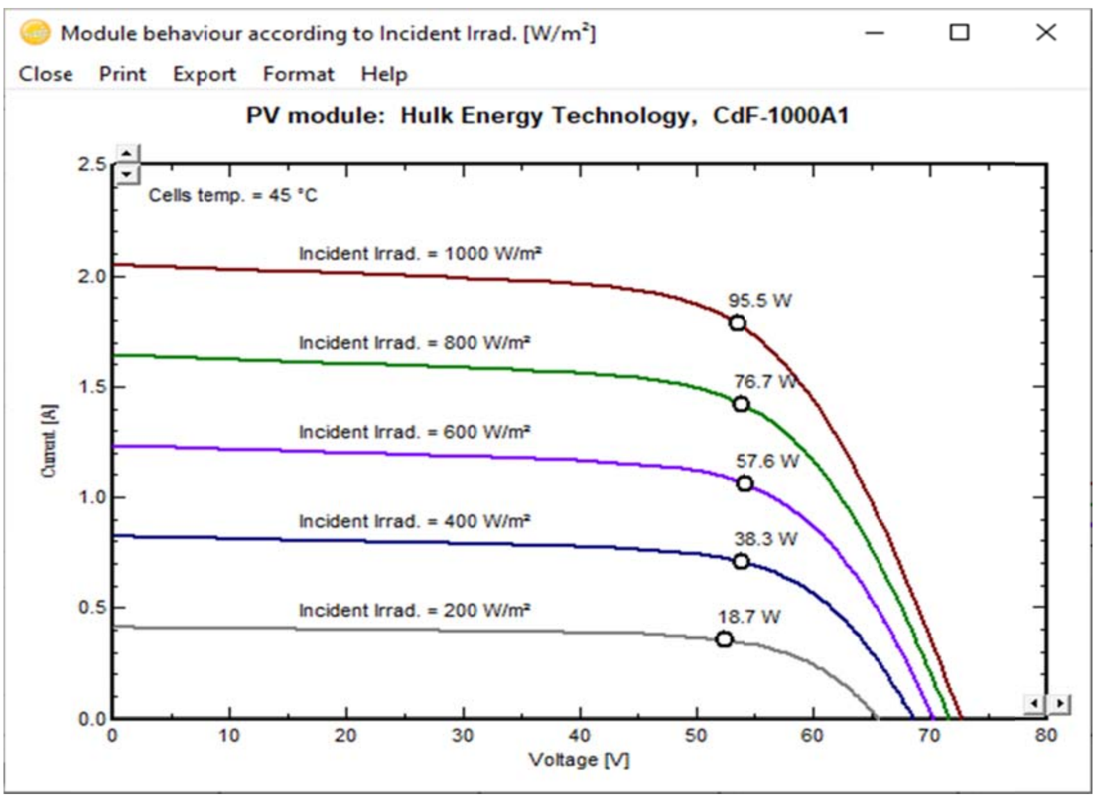

Figure 8 The current versus votage graph for the pv module depicting the module behaviour according to incident irradiation.

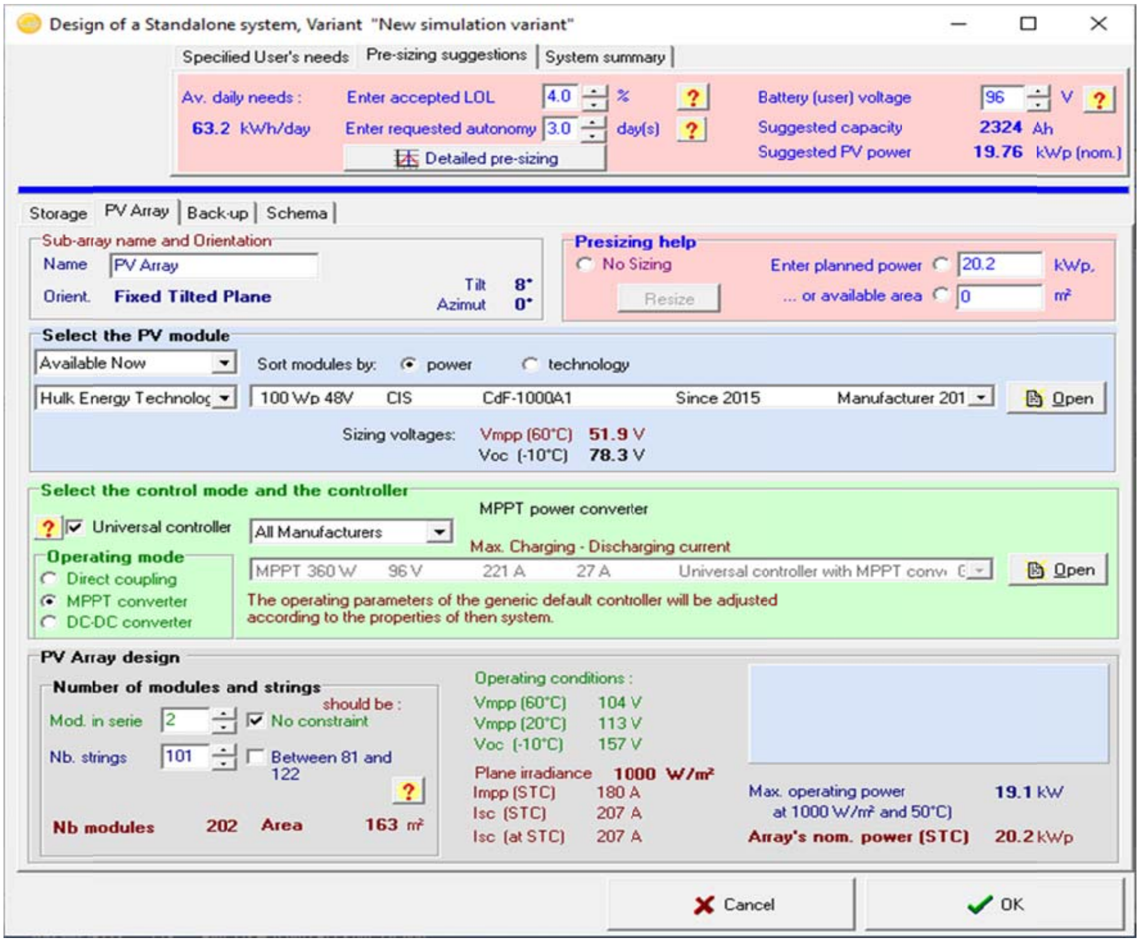

Figure 9 The PV Array configuration for the power system

3. Results and Discussion

A cut section of the main system parameters and main simulation results is in Figure 10 while the loss diagram is shown in Figure 11. The results in Figure 11 and Figure 12 show that the energy delivered to the load per year is 22.81 MWh. Also, as shown in the loss diagram of Figure 12, although the standard test condition (STC) energy yield is 34.08MWh however, the actual energy yield at the operating condition is 25.67 MWh while other losses including inverter, wire and battery losses reduce the actual energy delivered to the load to a value of 23.067 MWh.

The results on monthly and annual energy use and loss of load parameters are shown in Figure 13. The results showed that loss of load occurred in the months of July, September and October, as shown in Figure 13 and Figure 14. The daily loss of load duration for the month of July is shown in Figure 15, the daily loss of load duration for the month of September is shown in Figure 16, and the daily loss of load duration for the month of October is shown in Figure 17. The results in Figure 15 show that the loss of load (no power supply) occurred in the month of July, specifically from 8th of July to 10th of July, as well as from 16th to 17th of July, with a total of 52 hours of loss of load in July. The results in Figure 16 show that the loss of load (no power supply) occurred in the month of September, specifically from 19th to 20th of September, with a total of 19 hours of loss of load. Similarly, the results in Figure 17 show that the loss of load (no power supply) occurred in the month of October, specifically from 15th to 18th of October, with a total of 56 hours of loss of load.

In all, the annual loss of load probability is 1.44% which is less than the maximum allowed value of 3% based on the system design specification. As such, the designed solar power can effectively meet the power demand and satisfy the design specification.

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

Stand Alone System: Main results

Project : **COMPUTER_LAB_LOL**
Simulation variant : **New simulation variant**

Main system parameters	System type	**Stand alone**		
PV Field Orientation	tilt	8°	azimuth	0°
PV modules	Model	CdF-1000A1	Pnom	100 Wp
PV Array	Nb. of modules	202	Pnom total	**20.20 kWp**
Battery	Model	Dural SC	Technology	Lead-acid, vented, tubular
Battery Pack	Nb. of units	120	Voltage / Capacity	**96 V / 2250 Ah**
User's needs	Daily household consumers	Constant over the year	Global	23.07 MWh/year

Main simulation results				
System Production	**Available Energy**	**30.76 MWh/year**	Specific prod.	1523 kWh/kWp/year
	Used Energy	22.81 MWh/year	Excess (unused)	6.90 MWh/year
	Performance Ratio PR	64.84 %	Solar Fraction SF	98.86 %
Loss of Load	Time Fraction	1.4 %	Missing Energy	0.26 MWh/year

Figure 10 A cut section of the main system parameters and main simulation results

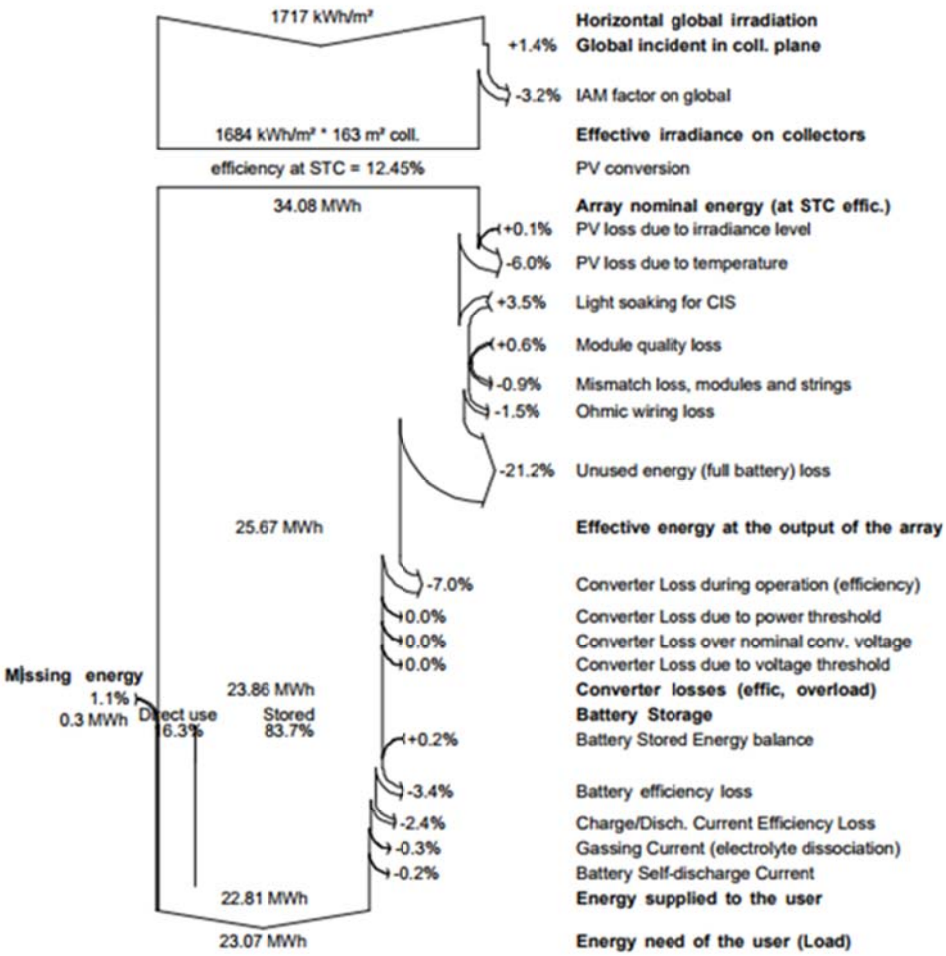

Figure 12 The loss diagram

Simulation variant : New simulation variant

Close Print Export Help

New simulation variant

Customised table

	EArray kWh	E Load kWh	E Miss kWh	E User kWh	T LOL Hour	Pr LOL %
January	2270	1960	0.0	1960	0	0.00
February	2008	1770	0.0	1770	0	0.00
March	2213	1960	0.0	1960	0	0.00
April	2133	1896	0.0	1896	0	0.00
May	2190	1960	0.0	1960	0	0.00
June	2089	1896	0.0	1896	0	0.00
July	2113	1960	86.0	1874	52	6.93
August	2129	1960	0.0	1960	0	0.00
September	2094	1896	39.3	1857	19	2.58
October	2064	1960	137.9	1822	56	7.54
November	2134	1896	0.0	1896	0	0.00
December	2229	1960	0.0	1960	0	0.00
Year	25666	23074	263.1	22811	126	1.44

Figure 12 The results on monthly and annual energy use and loss of load parameters.

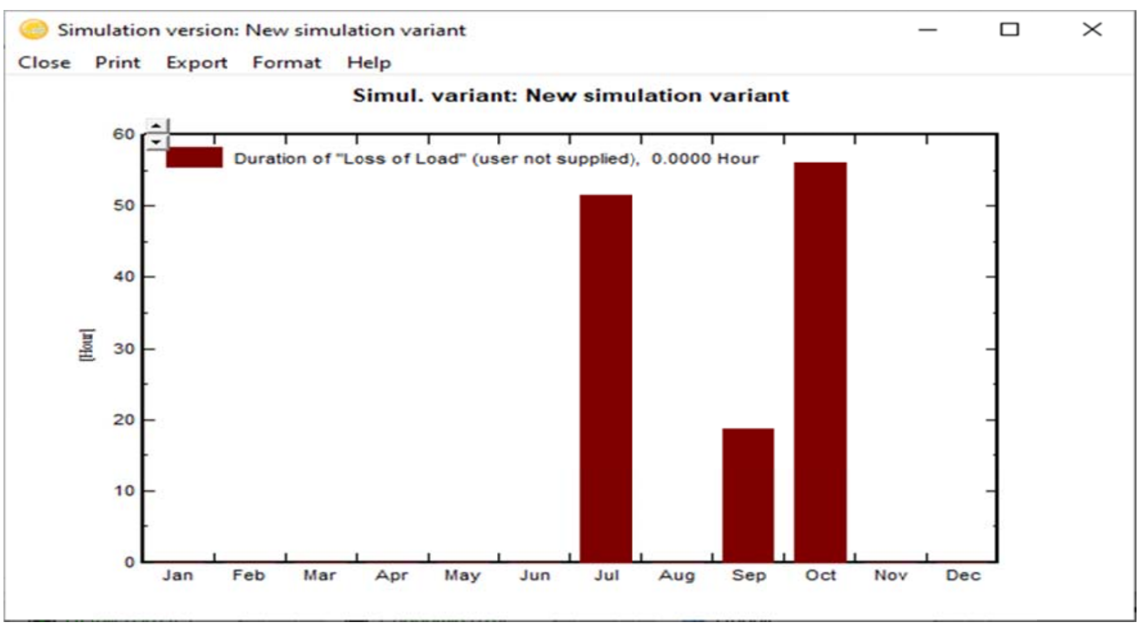

Figure 14 The monthly loss of load duration results showing that loss of load occurred in the months of July, September and October

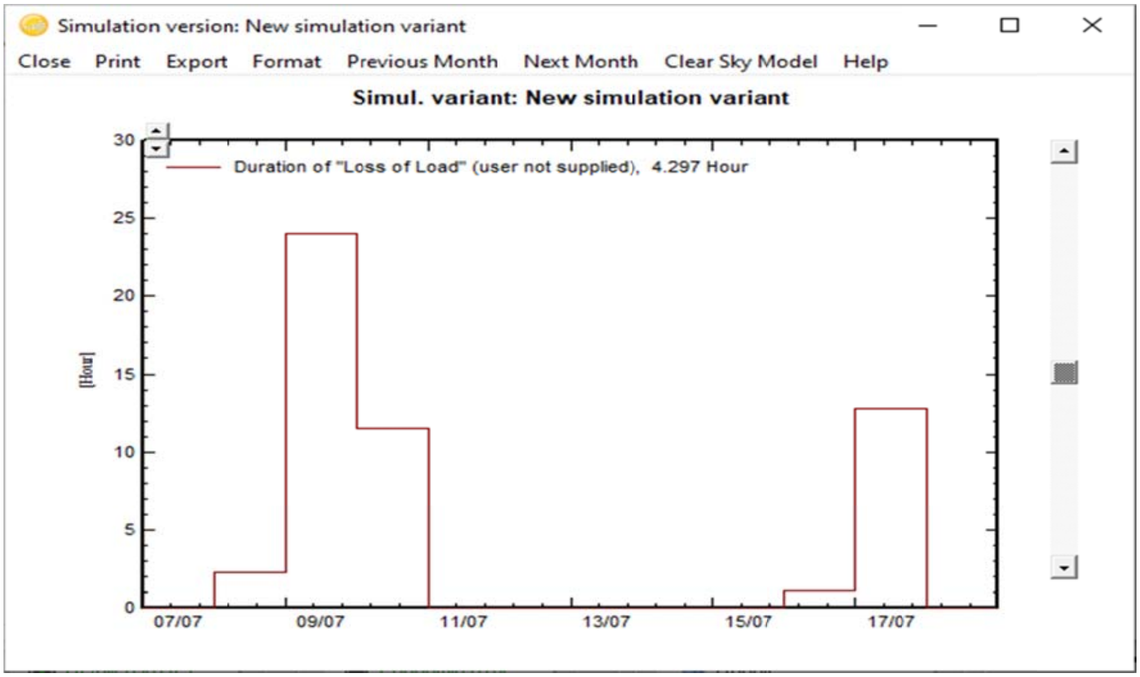

Figure 15 The daily loss of load duration for the month of July

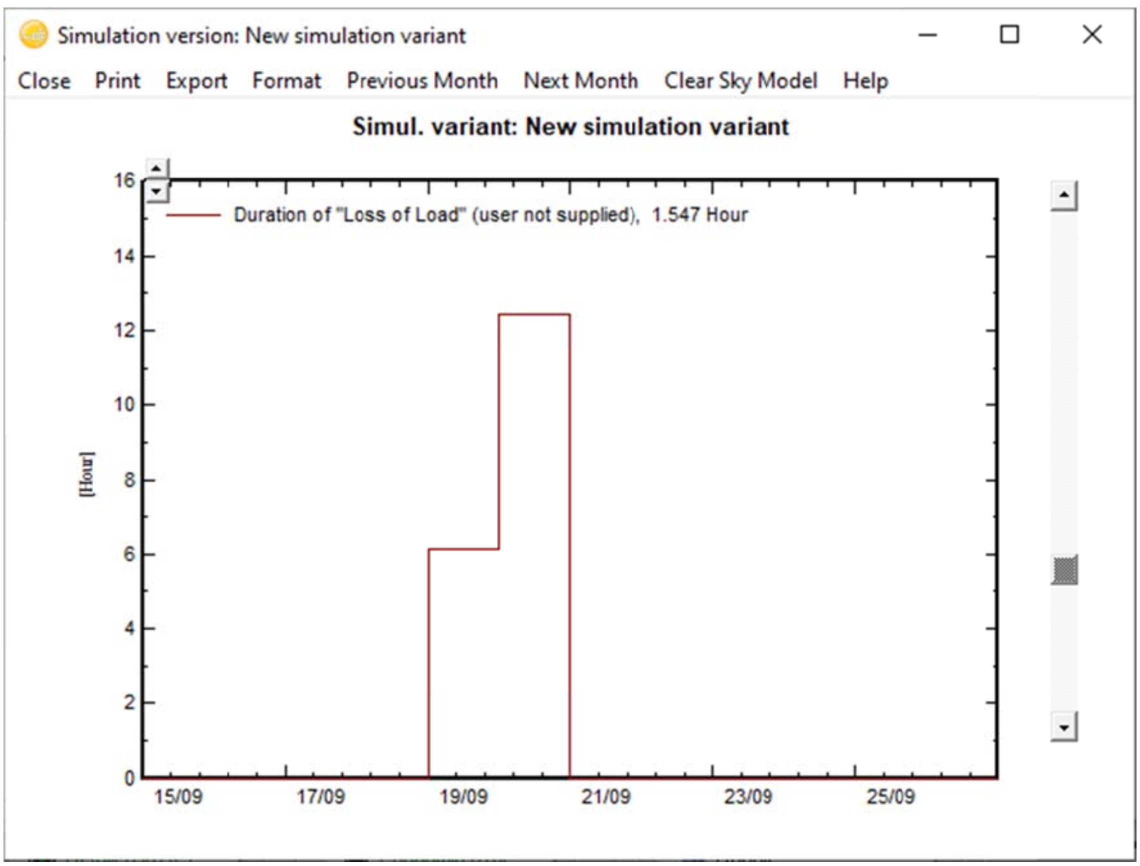

Figure 16 The daily loss of load duration for the month of September

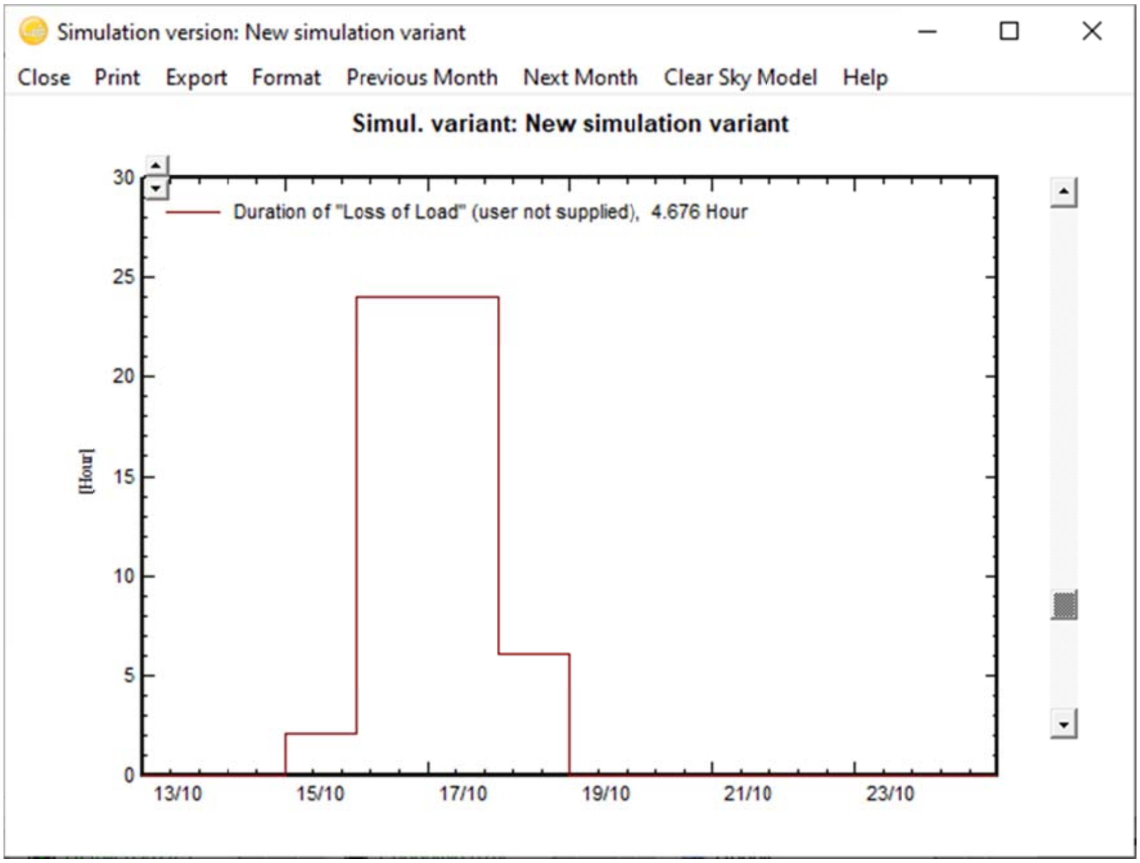

Figure 17 The daily loss of load duration for the month of October

4. Conclusion

PVSyst simulation software is used to simulate the loss of load parameters for off-grid PV installation for powering a computer laboratory. The load profile of the computer laboratory was used to establish the daily load demand while the latitude and longitude of the laboratory was used in PVSyst software to download the meteorological data used in the study. Also, the PVSYsyt software was used to select the various PV system components based on certain stated design specifications. The results show that the PV power system was able to satisfy the load demand with acceptable loss of load performance.

References

1. Lima, N., Viegas, C., & García-Peñalvo, F. J. (2019). Different didactical approaches using a remote lab: identification of impact factors. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, *14*(3), 76-86.
2. Alcaraz, R., Martínez-Rodrigo, A., Zangróniz, R., & Rieta, J. J. (2019). Blending inverted lectures and laboratory experiments to improve learning in an introductory course in digital systems. *IEEE Transactions on Education*, *63*(3), 144-154.
3. Estriegana, R., Medina-Merodio, J. A., & Barchino, R. (2019). Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model. *Computers & Education*, *135*, 1-14.
4. Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, *87*, 218-237.
5. Azlan, C. A., Wong, J. H. D., Tan, L. K., Huri, M. S. N. A., Ung, N. M., Pallath, V., ... & Ng, K. H. (2020). Teaching and learning of postgraduate medical physics using Internet-based e-learning during the COVID-19 pandemic–A case study from Malaysia. *Physica Medica*, *80*, 10-16.
6. Viegas, C., Pavani, A., Lima, N., Marques, A., Pozzo, I., Dobboletta, E., ... & Alves, G. (2018). Impact of a remote lab on teaching practices and student learning. *Computers & Education*, *126*, 201-216.
7. Johnston, A. N. B., Hamill, J., Barton, M. J., Baldwin, S., Percival, J., Williams-Pritchard, G., ... & Todorovic, M. (2015). Student learning styles in anatomy and physiology courses: Meeting the needs of nursing students. *Nurse education in practice*, *15*(6), 415-420.
8. Quiroga, M. D. M., & Choate, J. K. (2019). A virtual experiment improved students' understanding of physiological experimental processes ahead of a live inquiry-based

practical class. *Advances in Physiology Education*, *43*(4), 495-503.
9. Retnawati, H., Hadi, S., Nugraha, A. C., Arlinwibowo, J., Sulistyaningsih, E., Djidu, H., & Apino, E. (2017). Implementing the computer-based national examination in Indonesian schools: The challenges and strategies. *Problems of Education in the 21st Century*, *75*(6), 612.
10. Ajuwon, G. A. (2015). Internet accessibility and use of online health information resources by doctors in training healthcare institutions in Nigeria.
11. Agba, M. S., & Ocheni, S. I. (2017). An empirical study of the effects of work environment (electric power supply) on job performance of academic staff in Nigerian public and private universities. *Higher Education of Social Science*, *12*(2), 11-20.
12. 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*
13. 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
14. 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).
15. 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.
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. 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.
18. 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.
19. 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.
20. Dodo, U. A., Ashigwuike, E. C., Gafai, N. B., Eronu, E. M., Sada, A. Y., & Dodo, M. A. (2020). Optimization of an autonomous hybrid power system for an academic institution. *European Journal of Engineering and Technology Research*, *5*(10), 1160-1167.
21. Chmiel, Z., & Bhattacharyya, S. C. (2015). Analysis of off-grid electricity system at Isle of Eigg (Scotland): Lessons for developing countries. *Renewable Energy*, *81*, 578-588.
22. Chade, D., Miklis, T., & Dvorak, D. (2015). Feasibility study of wind-to-hydrogen system for Arctic remote locations–Grimsey island case study. *Renewable Energy*, *76*, 204-211.
23. 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.
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. 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).
26. 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.
27. 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.
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. Ball, J., Reicher, D., Sun, X., & Pollock, C. (2017). *The new solar system: China's evolving*

solar industry and its implications for competitive solar power in the United States and the world. Stanford Univ., CA (United States).

30. Haukkala, T. (2015). Does the sun shine in the High North? Vested interests as a barrier to solar energy deployment in Finland. *Energy research & social science*, *6*, 50-58.
31. Stokes, L. C., & Breetz, H. L. (2018). Politics in the US energy transition: Case studies of solar, wind, biofuels and electric vehicles policy. *Energy Policy*, *113*, 76-86.
32. Fraser, T., & Aldrich, D. P. (2020). The Fukushima effect at home: The changing role of domestic actors in Japanese energy policy. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(5), e655.
33. Aklin, M., & Urpelainen, J. (2018). *Renewables: The politics of a global energy transition*. MIT Press.
34. Kroposki, B. (2017). Integrating high levels of variable renewable energy into electric power systems. *Journal of Modern Power Systems and Clean Energy*, *5*(6), 831-837.
35. Worighi, I., Maach, A., Hafid, A., Hegazy, O., & Van Mierlo, J. (2019). Integrating renewable energy in smart grid system: Architecture, virtualization and analysis. *Sustainable Energy, Grids and Networks*, *18*, 100226.
36. Gautam, B. R., Li, F., & Ru, G. (2015). Assessment of urban roof top solar photovoltaic potential to solve power shortage problem in Nepal. *Energy and Buildings*, *86*, 735-744.
37. Rajbongshi, R., Borgohain, D., & Mahapatra, S. (2017). Optimization of PV-biomass-diesel and grid base hybrid energy systems for rural electrification by using HOMER. *Energy*, *126*, 461-474.
38. Lew, D., & Miller, N. (2017). Reaching new solar heights: integrating high penetrations of PV into the power system. *IET Renewable Power Generation*, *11*(1), 20-26.
39. Keerio, M. U., Ali, A., Saleem, M., Hussain, N., & Hussain, R. (2020, September). Multi-objective optimal reactive power dispatch considering probabilistic load demand along with wind and solar power integration. In *2020 2nd International Conference on Smart Power & Internet Energy Systems (SPIES)* (pp. 502-507). IEEE.
40. Tapetado, P., & Usaola, J. (2019). Capacity credits of wind and solar generation: The Spanish case. *Renewable Energy*, *143*, 164-175.
41. Singh, S. S., & Fernandez, E. (2015, December). Reliability evaluation of a solar photovoltaic system with and without battery storage. In *2015 Annual IEEE India Conference (INDICON)* (pp. 1-6). IEEE.