Journal of Asian Scientific Research
ISSN(e): 2223-1331
ISSN(p): 2226-5724
DOI: 10.18488/journal.2.2019.912.204.216
Vol. 9, No. 12, 204-216.

URL: www.aessweb.com

PERFORMANCE EVALUATION OF PROPOSED GRID CONNECTED SOLAR PHOTOVOLTAIC SYSTEM FOR ENGINEERING FACULTY, UNIVERSITY OF PORT HARCOURT

Omorogiuwa Eseosa[1+]
Oforji Kingsley[2]

[1,2]*Electrical/Electronic Engineering, Faculty of Engineering, University of Port Harcourt, Rivers State, Nigeria.*
[1]*Email: eseosa.omorogiuwa@uniport.edu.ng*

(+ Corresponding author)

Article History
Received: 19 August 2019
Revised: 23 September 2019
Accepted: 25 October 2019
Published: 2 December 2019

Keywords
Performance ratio
PVsyst
Capacity utilization factor
Grid connected PV plant
System yield factor
Photovoltaic.

ABSTRACT

Electrification of Faculty of Engineering (FOE) located in Choba Campus in University of Port Harcourt is often realized through distribution network from Port Harcourt Electricity Distribution Company (PHEDC). FOE buildings, each consists of two floors with basement, academic staff offices, administrative rooms and public facilities. Huge sum of money is spent daily to run generators and noise pollution has come to live with us. Nigeria however has immense exposure to solar radiation all through the year. It has highest daily solar radiation of 7.0KWh/m^2/day and lowest of 3.5KWh/m^2/day. Choba has average radiation of 4.55kWh/m^2/day and temperature of 27.23^{0}C. Choba is at 4^{0}49'27" North latitude and 7^{0}2'1" East longitude and altitude (elevation) of 20m (64ft). Load profile for FOE was carried out to determine the number of solar panels and inverter rating. Monthly average radiation was obtained from Nigeria meteorological agency between January 2014 to December 2018.The proposed PV system plant capacity is estimated at 100kW based on estimated load profile. Various tools such as system yield factor, capacity utilization factor, performance ratio were used in carrying out performance of 100kW PV system. Plots of I-V characteristics at constant irradiance, P-V characteristics at constant temperature and irradiance and efficiency curve of P-V panels were obtained. The PV is expected to meet 123,228.38kWh annual load demand for FOE, using PVsyst software. This supply period of electricity is between official hours of 8am to 4pm daily and estimated that annual DC energy generated from the system is 126619kWh/year, whereas available energy exported is 121914kWh/year.

Contribution/ Originality: The proposed PV system plant capacity is estimated at 100kW based on estimated load profile. Various tools such as system yield factor, capacity utilization factor, performance ratio were used in carrying out performance of 100kW PV system. Plots of I-V characteristics at constant irradiance, P-V characteristics at constant temperature and irradiance and efficiency curve of P-V panels were obtained. The PV is expected to meet 123,228.38kWh annual load demand for FOE, using PVsyst software. This supply period of electricity is between official hours of 8am to 4pm daily and estimated that annual DC energy generated from the system is 126619kWh/year, whereas available energy exported is 121914kWh/year.

1. INTRODUCTION

USAID [1] linked several challenges besieging Nigeria to poor power supply. It was also found that of the 45% total population of Nigeria that is connected to the grid, 36% population are rural dwellers and 64% are urban settlers (www.usaid.gov.powerafrica/nigeria, accessed April 13, 2019). Olatunji, et al. [2] presented lack of stable power supply as the root cause of high rate of unemployment and inflation in Nigeria. This in reality has resulted to close down of many businesses. Yemi [3] has attributed the deplorable state of Nigeria's power sector to structural inefficiency. The report further revealed that an average Nigerian enjoys significant portion of their electricity from private generators at higher cost (NGN 62-94/kWh) compared to supply from distribution companies of Nigeria. Over 95 million Nigerians are not connected to the grid, and even those that do have access experience very regular power outages. However, civilization and socio-economic development depend largely on constant power supply to meet daily growing demand. Poor attitude towards maintenance and sustenance of various sources of power supply is another factor besieging Nigeria power sector. Federal Ministry of Power and Housing [4] presented poor generation capacity of power to the deplorable state of the power network. Moreso, it is worthy of note that not all citizens are connected to the grid (www.power.gov.ng/2017/retrieved January 8, 2019). Lack of constant and sufficient power supply is a major challenge in present-day Nigeria, especially in Choba community which is a sub-hub of Port Harcourt where University of Port Harcourt is located. Presently, high cost of running generators in the faculty and noise pollution as a result of running such generators is another problem besieging Engineering Faculty. The aim of this paper involves performance evaluation of grid connected solar photovoltaic (PV) system for Engineering Faculty (FOE), University of Port Harcourt. The objectives are:

i. Assessment of electrical load demand of FOE, University of Port Harcourt.
ii. Collection of meteorological data from Nigeria Meteorological Agency between January 2014-December 2018.
iii. Determination of maximum electrical power that can be generated from the PV system.
iv. Determination of amount of electrical energy that the system can produce in a year.

2. REVIEW OF RELATED WORKS

Of the basic necessities of life, energy is the most significant for development and economic improvement. Among various types of energy, electricity has the most tremendous impact in the way of lives in the society. Hence, it is the duty of the government, among other things, to provide electricity to meet the growing demands of its citizens. Sadly enough, the present generation capacity in Nigeria is unable to meet the growing daily demand of electricity. World Energy Council [5] presented report showing that majority of the global population is not connected to the grid, (www.worldenergy.org/retrieved 12 January, 2019]). WEC presented a report which revealed that between 2000 and 2015, 8TWh of energy had been consumed In accordance with the view of Okozi, et al. [6] 60% of the entire population in Nigeria is without light. Even those having access are experiencing epileptic power supply. The researcher also attributed the poor state of the economy to the deplorable state of power sector. . With this consumption rate, it is now understandable why the climate is in a deplorable state, given that electricity is generated through conventional process (www.worldenergy.org/retrieved February 12, 2019). As a result of inadequate supply of power in most developed and underdeveloped nations, especially Nigeria, renewable sources are gradually getting attention as an alternative means of generating cleaner power supply. According to report from Renewable Energy Network for 21st century 2016 (www.ren21.net 2016/retrieved 24 April, 2019), a greater percentage of electricity that is made use of in the world is being generated through conventional process. Renewable and nuclear energy contribute a small percentage. This further gives reason for the poor state of the climate. Renewable Energy Network of 21st century 2018 (www.ren21.net/2018/retrieved 24 April, 2019), also presented that about 1.06 billion people do not have access to electricity, which account to 14% of global population. Further investigation shows that renewable energy capacity increased from 1000GW in 2007 to 2195GW in 2017.

Federal Ministry of Power [7] revealed that Nigeria has enough natural resources that can produce more electricity than is demanded if properly harnessed. But due to selfishness and the intention to amass unnecessary wealth, the nation's power sector has suffered serious setback (www.power.gov.ng/2013/accessed August 18, 2018). Other issues such as technical and socio-economic are also part of the reasons Nigeria power sector is dwindling over the years. Federal Ministry of Power [8] has turned to renewable energy sources in order to augment total energy mix as over 55% of Nigeria population is currently unconnected to the grid (www.power.gov.ng/2018/retrieved March 18, 2019). Barros, et al. [9] attributed the deplorable state of energy sector to selfishness and lack of political will by those at the helm of affairs. Globally, there is huge concern over conventional carbon-based energy production which includes increasing atmospheric carbon dioxide concentration from greenhouse gas emission, environmental safety of energy production techniques, fluctuation of energy prices and depleting carbon-based fuel reserve to name a few. Nigeria, whose most of its electricity is generated either by thermal power station or hydro power station, is not exempted from environmental challenges. This concern has prompted most countries to develop sustainable and clean energy system to provide growth and development, Shaaban and Petinrin [10]. Nayana, et al. [11] identified indigenous sources as panacea for lingering energy crisis and further suggested that more effort be concentrated towards tapping of solar energy sources. In addition, the researcher further stated that solar energy could solve both present and future energy consumption demand if dedicated attention is given to it. Maheshwari and Jain [12] describes rooftop solar plant as most efficient solar technology available which receives higher insolation compared to ground mounted system. It was also investigated that solar PV system is a pollution-free, environmental friendly and noise-free conversion process without moving parts.

2.1. Design Methodology

The method used is based on itemization of appliances with their corresponding power ratings and time of operation during the day to obtain total energy demand in watt-hour per day by the faculty. Total load was then used to determine the proposed grid connected solar PV system components sizes. Meteorological data was also obtained from Nigeria meteorological Agency to determine how its effect on the overall output of the proposed plant. Finally, performance ratio was used to estimate performance of the proposed solar PV plant.

2.2. Site Characteristics

. Nigeria has immense exposure to solar radiation all through the year. It has highest daily solar radiation of 7.0KWh/m^2/day and lowest of 3.5KWh/m^2/day. The University is located in Choba community, which is within the city of Port Harcourt in Rivers State of Nigeria. It was established in 1975 as a University College, Port Harcourt and was later given University status in 1977. Engineering faculty was established in 1983. The faculty is located in Choba and it consists of two buildings. Choba is located at 4^{0}49'27" North latitude and 7^{0}2'1" East longitude and altitude (elevation) of 20m (64ft). The faculty buildings, each consists of two floors with basement, academic staff offices, administrative rooms and public facilities. Electrification of the faculty is often realized through an electric distribution network. The university campus is an ideal topography for solar energy deployment. As at 2016, Port Harcourt urban area had an estimated population of 1,865,000 inhabitants, up from 1,382,592 as of 2006. The proposed PV power plant, which will cover electricity demand of the faculty, will be installed on the rooftops of the faculty buildings. 100kW grid-connected PV system is to be installed on the rooftop of the two buildings of the Faculty, University of Port Harcourt.

2.3. Load Profile

Due to variations in load demand during different times of the day, there is need to take accurate load profile of the faculty and also to determine the number of solar panels and inverter used. The load profile for the faculty is shown in Table 1.

Table-1. Typical electrical appliances used in FOE.

Appliances	Quantity	Unit power (W)	Working time (H)	Hours of operation (H)	Possible equip size (W)	Energy required/Day (Wh/Day)
Energy Bulb	908	18	08am– 4pm	8	16344	130752
Energy Bulb	25	40	06pm– 6am	12	1000	12000
A.C	4	1119	11am –4pm	5	4476	22380
Ceiling Fan	120	75	08am– 4pm	8	9000	72000
Standing Fan	8	60	08am– 1pm	5	480	2400
Fridge	12	100	08am– 4pm	8	1200	9600
Computer	21	300	08am– 4pm	8	6300	50400
Monitor	21	40	08am– 4pm	8	840	6720
Television	5	55		8	275	2200
Photocopier	6	2300		1	13800	13800
Printer	16	120	08am– 4pm	8	1920	15,560
Total			08am– 4pm		55,635	337,812

2.4. Climate Information

Before selecting site for PV system installation, meteorological data should be given primary consideration, especially solar irradiation and ambient temperature over a period of time. Table 2 shows monthly average radiation on the horizontal surface obtained from Nigeria Meteorological Agency. The data obtained span between January 2014 and December 2018.

From the data as shown in Table 2, the peak load which happens to reflect the appliance size of 100KW and daily load consumption is 338KWh/day.

2.5. Components Assessment

In the grid-connected solar PV system, energy is generated, converted and delivered to meet load demand. Excess of the generated power is fed into the local grid. In this study, solar PV is a module which directly converts solar energy to electricity. The grid-connected inverter converts DC voltage source to AC as required. The cost and performance of the system components are major factor in the design and costing.

2.6. PV System Layout

The proposed plant capacity is 100KW which is designed to meet the estimated daily load demand of FOE as presented in Table 1 and the total daily solar energy (G) in kWh/m^2/day. In order to satisfy the optimal system operation, different system parameters were considered.

2.6.1. PV Module

CS6X-315P-FG Canadian Inc solar panel model is chosen from the list of modules in the database of PV modules. Figure 1 shows system orientation of tilt angle of PV array. The module has peak power of 315Wp as shown in Figure 2. It is seen that 320 modules are required to design the proposed PV plant. The modules are connected in 40 parallel strings, with 8 modules in each. These 320 mono-crystalline silicon PV modules (panels) will generate 100KW power that will be fed into 100KW inverter. The PV system will be mounted on 625m^2 area of the building roof where it will receive best solar radiation; hence derives maximum amount of electricity from solar PV panels.

Table-2. meteorological data from NIMET.

	2014 data			2015 data			2016 data			2017 data			2018 data			Average		
Mth	**wind**	**solar**	**temp**	**wind**	**solar**	**temp**	**wind**	**solar**	**temp**	**wind**	**solar**	**temp**	**wind**	**solar**	**temp**	**wind**	**sola**	**temp**
Jan	2.40	4.383	27.90	2.40	4.795	27.30	3.00	4.709	26.80	2.40	5.026	29.90	2.10	4.867	28.00	2.46	4.647	27.44
Feb	2.50	4.824	28.40	3.20	4.838	28.20	3.10	4.853	28.30	3.20	5.242	30.00	2.40	5.155	29.40	2.88	4.782	28.86
Mar	2.50	4.766	28.30	2.70	4.666	27.70	2.40	4.680	27.90	2.70	4.766	28.80	2.70	4.701	28.20	2.60	4.716	28.18
Apr	2.50	4.752	28.10	2.70	4.680	27.80	2.40	4.738	28.10	2.70	4.234	26.80	3.00	4.694	28.10	2.62	4.620	27 78
May	2.40	4.594	27.60	2.70	4.709	28.00	2.60	4.608	27.70	2.70	4.234	26.60	2.10	4.536	27.50	2.50	4.536	27.48
Jun	2.30	4.277	26.20	2.80	4.781	28.20	2.90	4.219	26.30	2.70	4.500	27.00	2.30	4.349	26.90	2.60	4.425	26.92
Jul	2.50	4.147	25.60	2.50	4.162	25.80	2.40	4.118	26.00	2.40	4.176	26.10	2.60	4.190	25.90	2.48	4.159	25.88
Aug	2.70	4.190	25.90	2.70	4.118	26.00	2.50	4.104	25.80	2.70	4.234	26.20	2.10	4.133	25.80	2.60	4.152	25.94
Sept	2.70	4.248	26.30	2.80	4.500	26.90	2.70	4.291	25.60	2.60	4.406	26.90	2.80	4.291	26.40	2.72	4.347	26.62
Oct	2.30	4.421	26.60	2.10	4.550	27.10	2.00	4.421	26.90	2.2	4.651	27.70	2.00	4.486	26.90	2.12	4.506	27.04
Nov	1.90	4.493	26.80	1.90	4.493	27.60	1.90	4.666	27.80	2.00	4.752	28.10	2.00	4.579	27.40	1.94	4.597	27.54
Dec	2.10	4.594	26.40	1.80	4.594	27.300	2.60	4.882	26.30	1.80	4.766	27.70	2.00	4.538	27.80	2.02	4.675	27.10
Annual average values for wind(m/s), solar55kwh/m^2/day and temperatures (^{o}c) are : 2.47,4.55kwh/m^2/day and 27.44^{o}c																2.47	4.550	27.23

Source: NIMET.

2.6.2. System Orientation

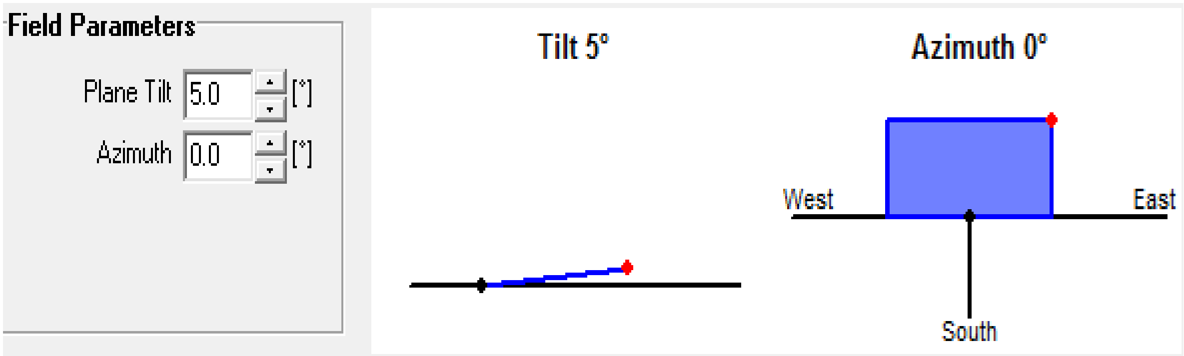

Figure-1. Tilt angle of PV array.

Source: PVsyst software.

Figure 1 describes the tilt angle of solar PV array for Choba site. In order to absorb maximum solar irradiance, the tilt angle must be inclined approximately equal to the latitude of the corresponding location. Since latitude of location is 4.8^0, it is then imperative to use tilt angle at 5^0 with Azimuth 0^0, meaning facing toward south.

2.6.3. Grid Tie Inverter

10 units of PV-10-1-OUTD-S1-US-480 grid-tie inverter are chosen from grid-tie inverter database of PVsyst programming software. Each of the inverter has a capacity of 10KWac with 120-470V operating system and maximum output voltage of 480V. Grid-tie inverter is an electrical device that converts the dc output voltage of the solar array into its ac equivalent. It can supply power at the same time with the electric utility grid when the inverter output synchronizes with those of the grid. In this grid-connected system, the inverter ought to be high enough to take care of total amount of watts needed at a time. The inverter capacity is 100KVA, which is connected to handle power from PV arrays of 100kWp rated output.

Table 3 shows the values and simulation parameters used to carry out the simulation for the grid connected system. These include the geographical site location, inverter ratings and size, PV array characteristics, cell area as well as cell to area with all their empirical values. This is as shown in the table.

Table-3. Grid connected simulation parameter.

Grid connected system	Simulation parameter	Grid connected system	Simulation parameter
Geographical site location	Latitude: 4.8^{0}N, Longitude: 7.0^{0}E	PV array characteristics	PV module model= CS6X-315P-FG
Collector orientation	Tilt=5^0		Manufacturer: Canadian Solar Inc
	Azimuth=0^0		Total no of PV modules:320
	Model used: Transposition perez		Series connection:8 Parallel string=40
	Horizontal=Free horizon		Unit of nominal power=315Wp
Inverter	Model= PV1-10-1-OUTD-S1-US-480		Array Global Power (STC)=101kWp
	Manufacturer=ABB		Operating condition=90.4
	Operating voltage=120-470V		Impp=346A, Vmpp=261V
	Unit of nominal power=10kWac	Cell area Total area	561m^2, 652m^2
	No of Inverter=10		
	Total power=100kWac		

Source: PV syst software.

2.6.4. Amount of Actual Energy Generation

Although 100kW is the proposed net installed capacity of the plant, this should not be seen as the actual output, reason being that energy produced by solar power plant depends so much on certain variables such as solar irradiance, daily temperature, number of sunny days and air mass, which are beyond the control of solar design engineers, as well as plant location, module efficiency, roof orientation, quality of equipment used and operation and maintenance culture which happen to be within the control of solar developer. Several losses occur in the system as presented by Habert [13] energy generated by the plant will be fluctuating and much lower than the nominal energy at the array. The identified low energy output to losses in the system. Saeed, et al. [14] described temperature, voltage drop, dirt and soil, shading, mismatch and inverter as major contributor to over 30% losses associated with grid connected solar PV system. In determination of number of solar PV module, Mevin, et al. [15] applied 30% losses in equipment sizing which ultimately increased number of modules required for the proposed plant.

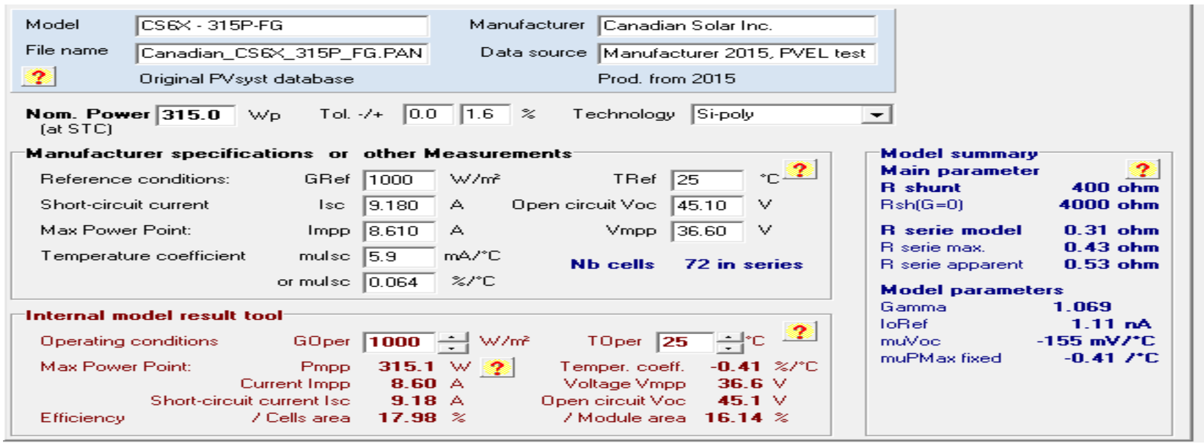

Figure-2. Module specification.

Figure 2 describes parameters of the module used in the design. Solar module model number is CS6X-315P-FG Canadian Inc solar panel model was chosen from the list of modules in the database of PV modules. The module has peak power of 315Wp. It has short circuit current Isc of 9.160A; open circuit voltage is 45.10V; maximum power point voltage (Vmpp) 36.60V and maximum power point (Impp) of 6.610A.

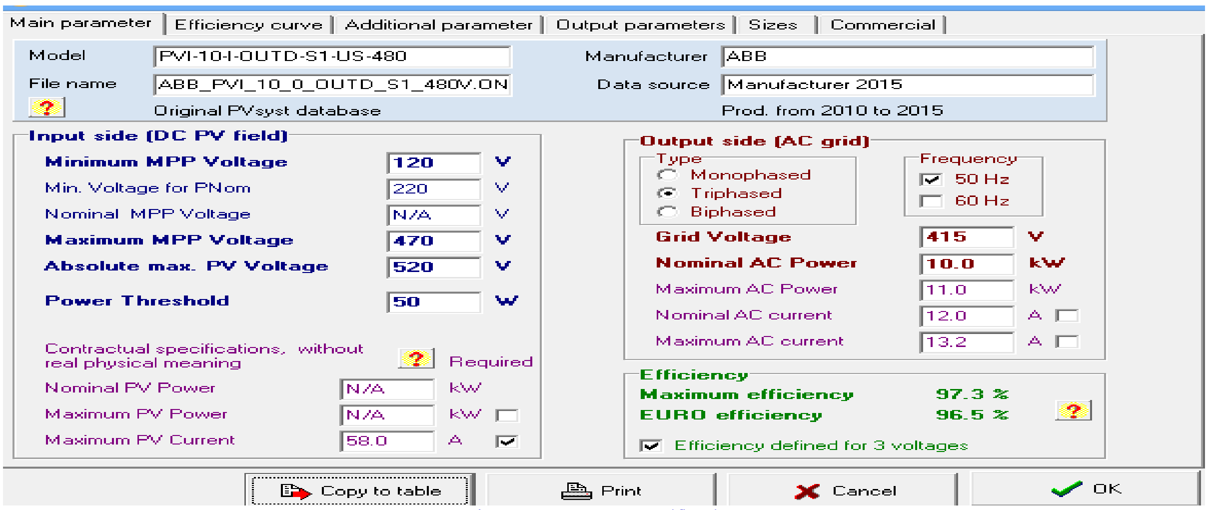

Figure-3. Inverter specification.

Figure 3 gives specification of grid tie inverter used in the design. PV-10-1-OUTD-S1-US-480 grid-tie inverter was chosen from grid-tie inverter database of PVSyst programming software. The capacity of inverter is 10KWac with 120-470V operating system and maximum output voltage of 480V. Maximum power point voltage is 1200V. It has minimum and maximum power points of 120V and 470V respectively. It is grid tie and as such is to be connected to 415V utility grid as specified in the parameter.

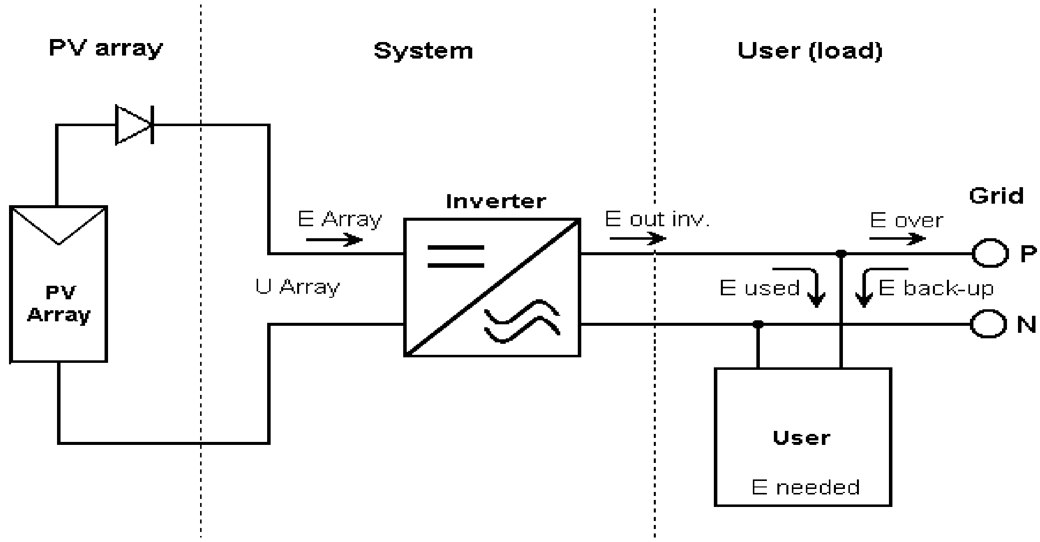

Figure-4. Model of grid connected solar PV system.

Source: PVsyst software.

Figure 4 shows proposed model of grid connected PV system as designed by PVsyst software. The model comprises three significant components, which are: PV array, grid-tie inverter system and load. The principal function of PV array is to convert solar energy into DC energy. The inverter converts DC energy into AC energy, which is then used by the load. During high irradiance, it is expected that solar PV system generated more energy than is needed by the user load so that excess would be exported to the grid. But at times of low irradiance, solar PV system generates less energy than is needed and the deficit is then supplied by the grid.

2.7. Tool for Performance Evaluation of Solar Power Plant

Several tools exist for performance evaluation of solar power plants. In this research work, performance ratio is employed to evaluate the performance of the proposed 100KW power plant for FOE, university of Port Harcourt in order to ascertain the viability of the project.

2.7.1. System Yield Factor (YF)

This refers to the ratio of the final energy at the output of inverter and the nominal power at the PV array. It describes the ratio of net energy that is produced over the lifespan of the plant It is expressed mathematically as:

$$Yf = \frac{EA}{Pmax\ STC} \quad 1$$

Where:

EA = amount of electrical energy generated by the PV power plant.

Pmax STC = total installed power of the solar module.

Yf unit is (kWh/kWp/day).

2.7.2. Capacity Utilization Factor (CUF)

This refers to the ratio of actual output energy from a solar plant over the year to the maximum possible output from it for a year under ideal condition. Usually, it is expressed in percentage as shown in Equation 2.

$$CUF = \frac{Actual\ Energy\ from\ the\ Plant\ (kWh)}{Plant\ Capacity\ (kWp) \times 24 \times 365} \quad 2$$

$$\mathbf{CUF} = \frac{121914}{100 \times 24 \times 365} = 13.9\%$$

2.7.3. Performance Ratio (PR)

According to Nayana, et al. [11] performance ratio can be expressed as the ratio of the actual energy generated to the theoretical possible power output of the solar PV plant. It is expressed as percentage. Several other factors such as losses are also considered. Performance ratio defines the quantity of energy that is actually exported to the grid. It is the most important parameter of PV plant which describes it performance and behavior to determine whether plant is in good shape or not. This parameter depends hugely on system losses.

Mathematically, it is expressed as shown in Equation 3.

$$PR = \frac{Actual\ Energy\ Generated\ (kWh)}{Theoretical\ Power\ Output\ of\ Plant\ at\ STC\ (kWh)} \quad 3$$

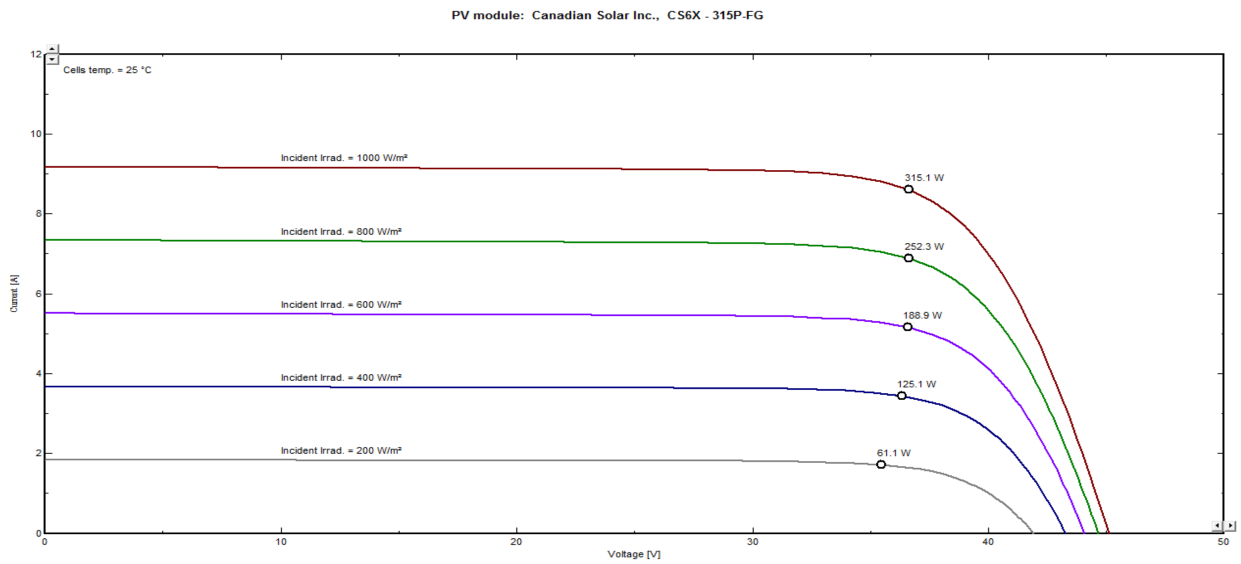

Figure-5. I-V Characteristics of solar panel used at constant temperature.

Figure 5 is a graph that illustrates I-V characteristics of the panel used for the study (CS6X-315P-FG) when subjected to constant temperature and variable irradiance condition. The figure clearly illustrates variation in voltage and current with changing irradiance when temperature is kept constant. It is observed that current increases slightly while voltage increases drastically when irradiance increases, and ultimately there is a corresponding increase in power. The graph also shows various levels of irradiances and their corresponding maximum power. It is also observed that the voltage at which maximum power is located is almost the same. At 200W/m^2, maximum power point is 61.6W; at 400W/m^2, maximum power point is 125.1W; at 600W/m^2, maximum power output is 188.9W; at 800W/m^2, maximum power point is 3252.3W; and finally, at 1000W/m^2, maximum power point is 315.1W. Each of the power output describes maximum power points at their corresponding irradiances.

3. RESULTS AND DISCUSSION

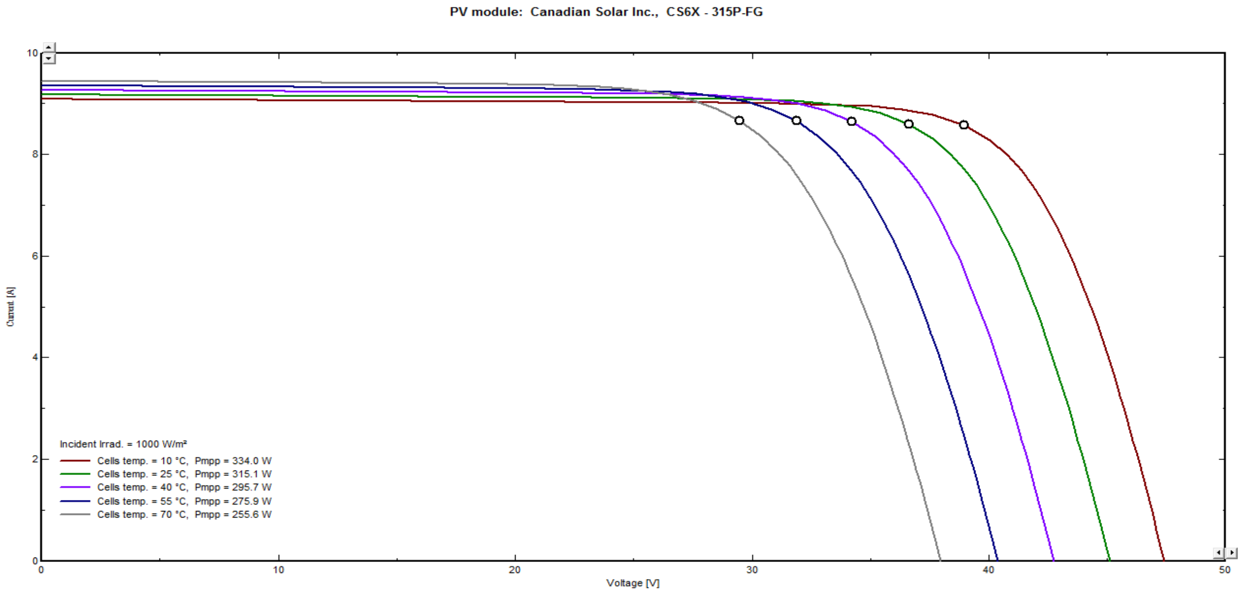

Figure-6. I-V Characteristics at constant irradiance.

Source: Researchers findings.

Figure 6 is a graph that describes the effect of changing temperature on the output of solar panel when irradiance is kept constant. It is observed that increase in temperature causes a slight increase in short circuit current and a drastic decrease in open circuit voltage; hence, there is overall decrease in output power. Each curve has a point at a particular voltage where the PV module produces maximum power output. This point is known as maximum power point. It is the nodes on the diagram. This maximum power point varies as irradiance and temperature vary. It is also observed that under influence of changing temperature, maximum power points are located at various points of operating voltages, which are far from each other. At 10⁰C, maximum power point is 334W; at 25⁰C, maximum power point is 315.1W; at 40⁰C, maximum power point is 295.7W; at 55⁰C, maximum power point is 275.9W; at 70⁰C, maximum power point is 255.5W.

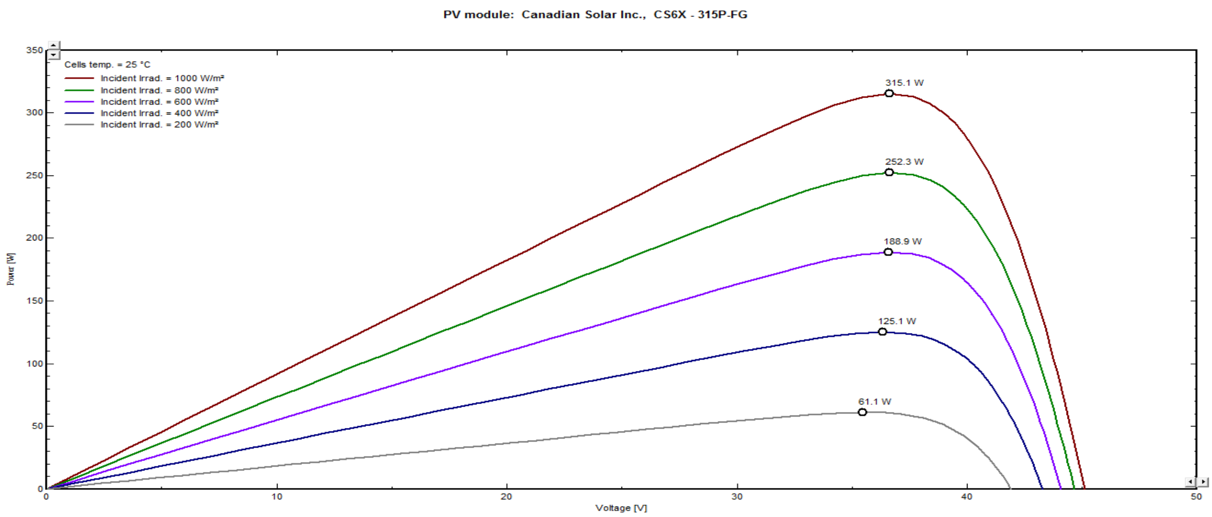

Figure-7. P-V characteristics at constant temperature.

Figure 7 is a graph that describes relationship between various levels of irradiance and their corresponding maximum power points. It is observed that when irradiance increases at constant temperature, there is corresponding increase in maximum power point and vice versa. At 200W/m^2, maximum power point is at 61.1W;

at 400W/m², maximum power point is at 125.1W; at 600W/m², maximum power point is at 188.9W; at 800W/m², maximum power point is at 252.3W; at 1000W/m², maximum power point is at 315.1W. Increase in irradiance results in more power generated from the PV system.

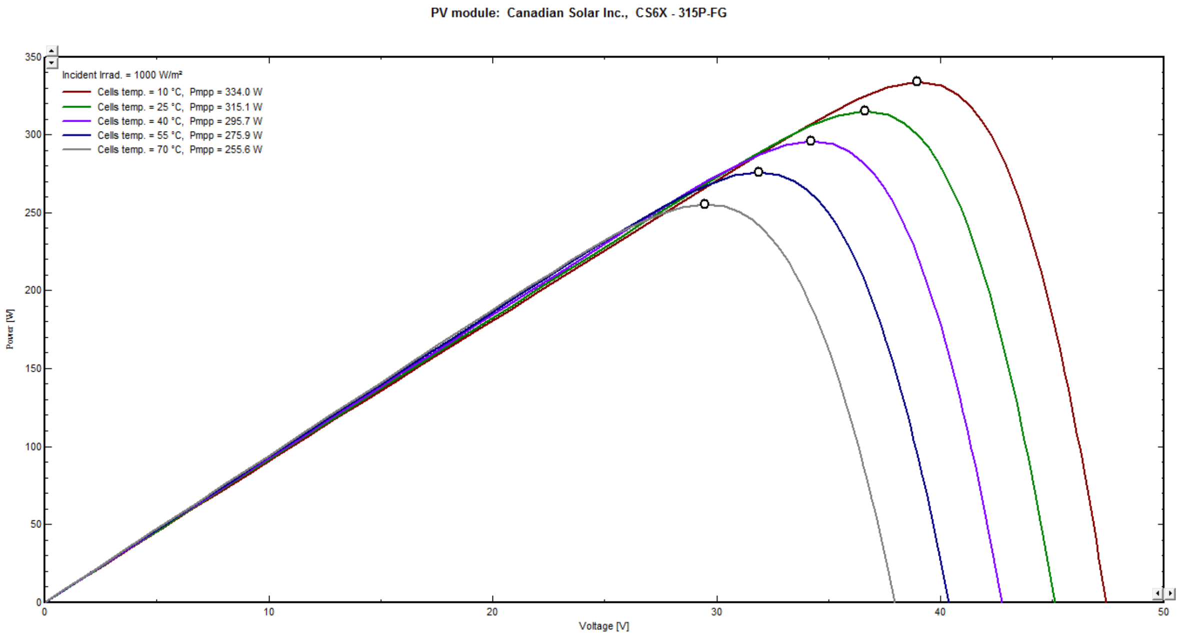

Figure-8. P-V Characteristics at constant irradiance.

Figure 8 also illustrates the impact of changing temperature on power output of solar module. Temperature is inversely proportional to output power of the module as shown in the graph. When temperature is 100C, power produced was observed to be 334W; as temperature increased to 250C, power output dropped to 315.1W; further increased in temperature to 400C led to further decrease in power output to 295.7W; at550C, power produced became 275.9W; and finally, at 700C, maximum power output was 255.6W.

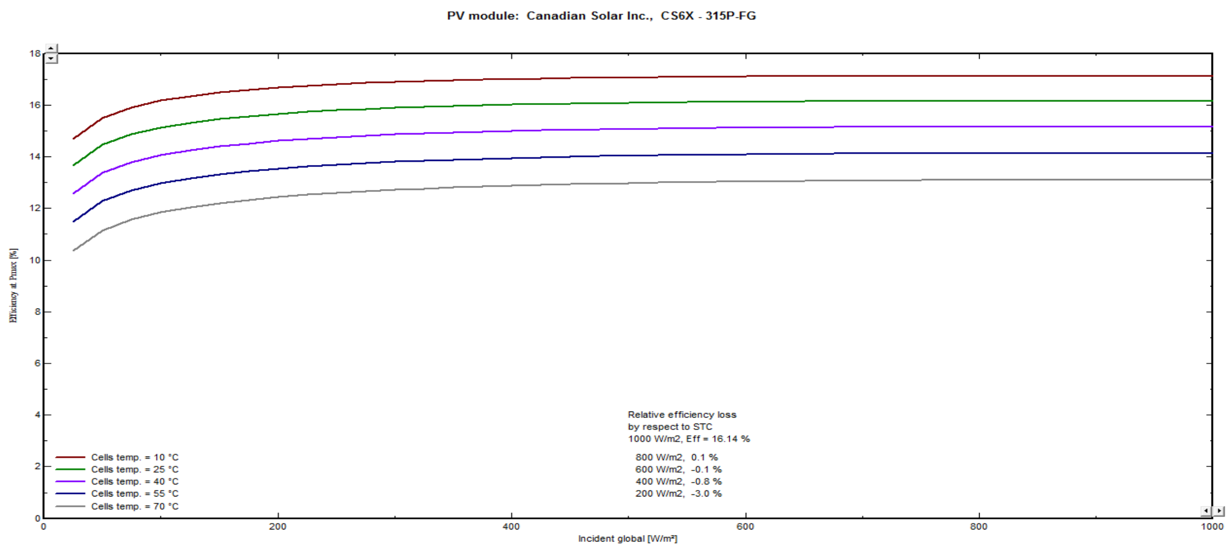

Figure-9. Efficiency curve of PV panel.

Source: Researchers findings.

Figure 9 is efficiency curve of PV panel that illustrates relationship between temperature and panel efficiency. Temperature is inversely proportional to efficiency. As temperature increases, efficiency of panel decreases as shown in the graph.

3.1. Discussion of Findings

The site for the proposed grid connected PV system receives annual average energy of 1474kWh/m²/year. The annual performance ratio of the system is 81.1% and capacity utilization factor of 13.9%. With nominal energy of 144.6MWh and useful energy of 121.9MWh, it is estimated that over 80% of total energy is exported to point of utilisation. These useful findings indicate that the PV system will be operated with good performance ratio and capacity utilization factor. It is also indicative of the fact that it will feed enough power at maximum available percentage.

Factors such as irradiance and temperature have tremendous impact on the power output of the system. PV system should be sited where appreciably high irradiance and temperature close to standard test condition of the panel, as temperature adversely affects efficiency of panel. Subsystems of the PV system contribute to various levels of losses as power travels from one point to another and during conversion process. This also affects efficiency of the entire system. In order to absorb maximum solar irradiation, solar PV array should be tilted at angle approximately close to the latitude of the location. This will help in effective utilization of incident radiation on the array.

4. CONCLUSION

This work focused more on performance evaluation of grid-connected solar PV system for FOE, University of Port Harcourt. FOE represents an ideal site for installation of solar PV system as the location records high insolation because the present generation capacity and use of private generators to provide electricity in FOE faces enormous logistical challenges making it less cost effective with very high operating cost. This work evaluated the performance of proposed grid connected PV system with a view to providing reliable, cost effective and clean solution for power supply deficiency in FOE. The present power supply from the Power Holding Company of Nigeria (PHCN) is very unstable and unreliable as huge sum of money is spent on running generators on daily basis.

Funding: The authors wish to acknowledge the management and staff of Eseogietec Engineering Limited situated in Port Harcourt, Nigeria (www.eseogietec.com) for their support financially and academically towards the completion of this investigation.
Competing Interests: The authors declare that they have no competing interests.
Acknowledgement: Both authors contributed equally to the conception and design of the study.

REFERENCES

[1] USAID, "Nigeria power Africa fact sheet." Avaliable https://www.usaid.gov/powerafrica/nigeria. [Accessed 13 June, 2019], 2019.

[2] O. Olatunji, S. Akinlabi, A. Oluseyi, A. Abioye, F. Ishiola, M. Peter, and N. Madushade, "Electricity power crisis in Nigeria: A strategic call for change of focus to renewable source," presented at the 10P Conference Series: Material Science and Engineering, 2018.

[3] O. Yemi, "Nigeria power baseline report." Available: http://www.nesistats.org/uploads/3/4/9/3/34934878/ner.pdf. [Accessed August 15, 2015], 2015.

[4] Federal Ministry of Power and Housing, "Daily operational report. Available: https://www.pwh.gov.ng. [Acessed November 12, 2018]," 2017.

[5] World Energy Council, "World energy resources IEA, electricity information, Paris." Available: http://www.worldenergy.org/. [Accessed 2019 April 20], 2016.

[6] S. O. Okozi, N. F. C. Paulinus, E. C. Ezeugwu, and N. A. Ndubuisi, "Energy crisi in Nigeria-the way forward," *International Journal of Engineering Research and Management*, vol. 4, pp. 4-7, 2017.

[7] Federal Ministry of Power, "Investment opportunities in the Nigerian power sector." Available: https://www.pwh.gov.ng [Accessed August 18, 2018], 2013.

[8] Federal Ministry of Power, "Press briefing: 90 million Nigerians without electricity. Sahara Reporters, New York, March 6, 2018." Available: https://www.pwh.gov.ng. [Accessed August 18 2018], 2018.

[9] C. P. Barros, A. Ibiowie, and S. Managi, "Nigeria's power sector: Analysis of productivity," *Economic Analysis and Policy*, vol. 44, pp. 65-73, 2014. Available at: https://doi.org/10.1016/j.eap.2014.02.003.

[10] M. Shaaban and J. Petinrin, "Renewable energy potentials in Nigeria: Meeting rural energy needs," *Renewable and Sustainable Energy Reviews*, vol. 29, pp. 72-84, 2014. Available at: https://doi.org/10.1016/j.rser.2013.08.078.

[11] M. Nayana, N. H. Sunitha, and Y. Siva, "Performance evaluation of 10MWp solar power plant at Shiva Samudram power station," *International Journal of Electronics Engineering Research*, vol. 9, pp. 1099-1108, 2017.

[12] H. Maheshwari and K. Jain, "Financial viability of solar photovoltaic system: A case study," *International Journal of Civil Engineering and Technology*, vol. 8, pp. 180-190, 2017.

[13] A. W. Habert, "Installing grid connected solar PV workshop. Republic of Fiji. November, 21-21," 2010.

[14] E. Saeed, A. Mehran, I. Masoud, T. Hakimeh, and G. Maysam, "Technical and economic assessment of grid connected photovoltaic power plants: Iran case study," *Energy*, vol. 114, pp. 923-934, 2016. Available at: https://doi.org/10.1016/j.energy.2016.08.041.

[15] C. Mevin, G. Agrawal, S. Mathur, and A. Mathur, "Techno-economic analysis of solar photovoltaic power plant for garment zone of Jaipur city," *Case Studies in Thermal Engineering*, vol. 2, pp. 1-7, 2014. Available at: https://doi.org/10.1016/j.csite.2013.10.002.