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Design and Model of a Photovoltaic Solar Farm for the Power System Stability of the Federal University of Kashere, Gombe, Nigeria.

Ohakwere-Eze M. C., Nosike C. and Singh S. K.
[1]Department of Physics, Federal University of Kashere, Gombe State, Nigeria.
***Corresponding Author**: michael.coat@fukashere.edu.ng; +2347035746293

Abstract
Solar energy is radiant light and heat from the sun that is harnessed using a range of ever-evolving technologies. There is a need to embrace the utility of solar power for supplying of electricity in the Science faculty building and moreover model the implementation to other faculty buildings and the University at large. This is to ensure non-interruption of the power as a blackout will hinder the progress of many crucial pro-academic activities like research, teaching, laboratory activities etc. The design was done using solar modules, inverters, batteries and charge controllers. The components and sizing of the PV system modeled is tare sequel to the analyses of both the total load capacity and total energy consumption. The analyses have shown that the building has a total load capacity of 20.97KW and require total energy consumption of 46.46KWH. From the design, 84 of 125W modules, 10 of 24V, 40A charge controllers, 32 of 12V, 200Ah batteries and 18 of 1.5KVA inverters will be needed to construct the solar farm for the Faculty of Science building of the University hence solve the issue of interrupted power outages in the building. The implication of the research will help efficient deployment of a solar farm that will solve the basic energy need of the faculty building.

Keywords: solar farm, energy, renewable energy, power

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Introduction
Solar energy was used by humans as early as 7th century B.C. when history tells us that humans used sunlight to light fires with magnifying glass materials. Later, in 3rd century B.C., the Greeks and Romans were known to harness solar power with mirrors to light torches for religious ceremonies. These mirrors became a normalized tool referred to as "burning mirrors." Chinese civilization documented the use of mirrors for the same purpose later in 20 A.D. (Richardson, 2018). In 1839 Alexandre Edmond Becquerel discovered the photovoltaic effect which explains how electricity can be generated from sunlight. He claimed that shining light on an electrode submerged in a conductive solution would create an electric current (Fonash, 2018). However, even after much research and development subsequent to the discovery, photovoltaic power continued to be very inefficient and solar cells were used mainly for the purposes of measuring light.

About a century later, in 1941, Russell Ohl invented the solar cell, shortly after the invention of the transistor. Light (photons) striking certain compounds, in particular metals, causes the surface of the material to emit electrons and on striking other compound, causes the material to accept electrons. The simultaneous emitting and accepting of electrons by these two compounds cause the electricity to be generated in a conductor (Fonash, 2018).

The Federal government, states and private investors in Nigeria have invested over $20 billion on new 20 solar projects, targeted at boosting supply in the country. The new projects include the $479 million Shiroro project, Niger State, $5 billion Delta State utility-scale solar project, $2.3 billion University of Ilorin solar power plant and $1 billion Firstgate solar park (Udeme and Prince, 2017).

Solar energy is radiant light and heat from the sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar terminal energy, molten salt power plants and artificial photosynthesis. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar, depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the sun, selecting materials with favorable thermal mass or light–dispersing properties and designing space that naturally circulates air.

Solar Power is a clean renewable resource with zero-emission that has got the tremendous potential of energy that can be harnessed using a variety of devices. With recent developments, solar energy systems are easily available for industrial and domestic use with the added advantage of minimum maintenance. Most of the developed countries are switching over to solar energy as one of the prime renewable energy sources. The current architectural designs make provision for photovoltaic cells and necessary circuitry while making building plans. Renewable energy is the way modern society is growing fear in some quarters that solar energy cannot power high power demanding machinery and appliances is baseless as it is capable of powering all that the conventional grid electricity can power (Ayodeji, 2017).

In addition to the positive aspects of using sunlight, the photovoltaic system is more efficient, has no critical size and indeed size can be matched to load with little loss in efficiency, can be physically located near the load and are environmentally benign in operation. It is thus one of the most attractive future technologies (Ohakwere-Eze, 2015).

Several attempts made by the government to stabilize electricity in Nigeria, solar initiatives seem to have made much better headway. In July 2017, two communities in Kaduna, Gnami and Pakau celebrated 2 years of uninterrupted power from the 90-kilowatt solar Photovoltaic (PV) off-grid system installed in the areas — as the villages are far from the reach of the national power grid (Okechukwu, 2016).

Nigeria's first solar plant was inaugurated in the University of Ibadan. According to the Federal Government, the plant will, when completed, power three universities and their environment by supplying 10 megawatts of renewable energy. Just eight months after this, another solar project — the completion of the first set of solar-powered estates in Abuja was announced in June 2017 (Okafor, 2017).

Recently renewable energy met 100% of Portugals power demand for three days, according to data by purtuguess power utility, Redes Energicas Nacionais (Morais, 2018). This is awesome, the first time in history where the overall energy consumed by the whole country is generated from renewable energy resources. There is high possibility that renewable energy would soon prevail in the near future. (Anyakoha, 2011).

The research work seeks to provide a suitable solution to the power challenges facing the University. Every organization (formal or informal) need the power supply for its effective and efficient running. Looking into the situation of the school environment and imagine how the staff and students may be inconvenienced at the event of power interruption, one would deem it necessary to embrace renewable energy source as the best alternative to the power problem. The faculty of Science building, houses both the teaching and non-teaching staff of the University. They are actively engaged in school activities most of which involve the use of electricity to power the appliances. However, office, as well as academic activities, are interrupted due to the black-out.

The aim of the study is to model a solar PV farm to cater for the basic energy consumption of the Faculty of Science building, Federal University of Kashere moreover recommend its implementation.

The research objectives in regard to the study are to plan for energy need in the faculty of science building; to provide a preview of the influence of solar energy in a formal setting; to show how solar energy can be the best alternative way of tackling prothe blem of power failure in the university; to reduce to the barest minimum the power challenges facing the school. This research work is carried out by covering the energy consumption of the Faculty of Science building. However, heavy loads such as Refrigerators and Air-conditioners are not incorporated.

Materials and Methods

The components and sizing of the PV system used is explained in this section. The major components include solar modules, inverters, batteries and charge controllers.

Load Sizing

The energy requirement E is calculated as follows.

$$E = P \times H + P_L \qquad (1)$$

where,
E is the energy requirement (Watt-Hour)
P is the load power (Watts)
H is the hour of operation (Hour) and
P_L is the provision for losses (Watts)

Inverter Sizing

The inverter sizing is calculated as:

$$Iv_s = P_T + I_S \qquad (2)$$

where
Iv_s is the Size of inverter,
P_T is the total power of AC load and
I_S is the provision for starting current of some loads.

Battery Sizing

Battery sizing is calculated from the equations below.

$$B_{SC} = E \times D / DOD \qquad (3)$$

where,
B_{SC} is battery storage capacity
E is the ampere-hour
D is the days of autonomy and
DOD is the depth of discharge.

$$B_P = B_{SC} / B_C \qquad (4)$$

Where,
B_P is the number of battery in parallel
B_{SC} is the battery storage capacity and
B_C is the rated capacity per battery

$$B_{ser} = V/V_B \qquad (5)$$

where,
B_{ser} is the number of batteries.
V is the system voltage and
V_B is the batteries voltage.

$$B_{tot} = B_P \times B_{ser} \qquad (6)$$

where,
B_{tot} is the total number of batteries
B_P is the number of battery in parallel and
B_{ser} is the number of batteries.

Array Sizing

One can calculate how many solar panels needed by multiplying the household's hourly energy requirement by the peak sunlight hours for your area and dividing that by a panel's wattage. This give the number of panels (array size) needed for the households. Module sizing is obtained by:

$$M_{par} = I_C / I_{mp} \qquad (7)$$

where,
M_{par} is the Number of Modules in parallel,
I_C is the charging current and
I_{mp} is the power point

$$M_{ser} = V_{sys}/Vn \qquad (8)$$

where,
M_{ser} is the number of module in series
V_{sys} is the system voltage and
Vn is the module nominal voltage.

Charge Controller Sizing

Each time solar panels is used to charge batteries, it's necessary to use a charge controller in the circuit in order to protect the battery from overcharging or from over-discharging. The Exception to this rule is when using solar panels smaller than 5 watts. Charge controller sizing is calculated from the equation below.

$$I_{cc} = M_P \times I_{sc} \times F_S \qquad (9)$$

Where

I_{cc} is the charge controller sizing,

M_P is number of Modules in parallel,

I_{sc} is the short circuit current and

F_S is the factor that account for loss in the system.

Results

The data obtained from the field are presented in the tables. Information in each table depicts the analysis of load contained in each room/office in the faculty of science building. No single room/office was omitted or ignored. Care was taken in the process of collecting the data by ensuring that all the appliances in each room and office were included for high reliability and accuracy of result.

Load analysis

Data obtained from the field are shown in the tables below. Information in each room/office in the Faculty of Science building are first analyzed separately in a table to show the energy consumption in each office thereby making it easy to compute the estimate of overall energy consumption in the faculty building. Consequently, the necessary calculations are computed and results are obtained.

Table 1: Load analysis of office of D.V.C

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	8	130	1040
2	Bulb	5	15	8	75	600
3	Laptop	4	65	5	260	1300
4	Printer	-	-	-	-	-
5	Desktop	-	-	-	-	
	Total				465	2940

Table 2: Load analysis of Office of Dean

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	8	130	1040
2	Bulb	6	15	5	90	450
3	Laptop	3	65	5	195	975
4	Printer	2	1200	1	2400	2400
5	Desktop	-	-	-	-	-
	Total				2815	4865

From table 1, it is evident that the power developed on daily basis in the office is 465W. The overall energy use is 2940Wh – a value obtained by summation of product of power developed in a day by each appliance and the hours of use (H.O.U).

In table 2, the estimate of total energy use on daily basis is 4865Wh and the equivalent power developed by all the appliances in the office is 2815W. When the printer is use for an hour in a day, it uses nearly 50% of the energy consumed by all the appliances in the office. Therefore, it is advisable that other appliances be switch off, if the printer is to operate for more than one hour. This is to ensure long and healthy functionality of some system components.

Table 3: Load analysis of Conference Room

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	6	65	5	390	1950
2	Bulb	8	15	4	120	480
3	Laptop	-	-	-	-	-
4	Printer	-	-	-	-	-
5	Desktop	-	-	-	-	-
	Total				510	2430

Table 4: Load analysis of staff office

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	7	130	910
2	Bulb	2	15	5	30	150
3	Laptop	6	65	4	390	1560
4	Printer	-	-	-	-	-
5	Desktop	-	-	-	-	-
	Total				550	2620

Table 3 shows the load analysis of the conference room. It is obvious that the daily approximate energy requirement of the room is 2430Wh and the power equivalent of all appliances base on the hour of use of each appliance is 510W. However, when the meeting is held in the room, a few appliances like a laptop and mobile phones may be plugged in. This increase in the energy is compensation for the unused energy during the period of time the meeting is not held in the room and the ceiling fans and bulbs should be switch off.

From table 4, the total energy use in the staff office is 2620Wh, the equivalent power develops by the appliances in the office is 550W. At the event of having more staff plug-in their laptops, ceiling fans and bulbs should then be operated for less period of time.

Table 5: Load analysis of Chemistry Department

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	6	130	780
2	Bulb	5	15	6	75	450
3	Laptop	3	65	5	195	975
4	Printer	2	1200	1/2	2400	1200
5	Desktop	2	240	1/2	480	240
	Total				3280	3645

Table 6: Load analysis of the Biology Department

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	6	130	780
2	Bulb	5	15	5	75	375
3	Laptop	-	-	-	-	-
4	Printer	1	1200	1/2	1200	600
5	Desktop	5	240	2	1200	2400
	Total				2605	4155

Table 5 depicts the load analysis of chemistry department. The printer consumes about one-third of the total energy requirement in the department on a daily basis of operation of the appliances. Since printing is seldom, less energy is used during the period the printer is not in use.

As shown in table 6, the approximate energy requirement in biological science department is 4155Wh and the equivalent power develop by the appliance is 2605W (the estimates are on average per day).

Table 7: Load analysis of Mathematics Department

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	6	130	780
2	Bulb	2	15	8	30	240
3	Laptop	2	65	4	130	520
4	Printer	2	1200	1/2	2400	1200
5	Desktop	2	240	3	480	1440
	Total				3170	4180

Table 8: Load analysis of office of Dean Student affair

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	6	130	780
2	Bulb	3	15	7	45	315
3	Printer	1	1200	1/2	1200	600
4	Desktop	1	480	3	480	1440
	Total				1855	3135

Table 7 above reveals the load analysis of the mathematical department. The approximate energy requirement is 4180 and the equivalent power of all the appliances is 3170 on the average of duration of use of each appliance per day.

From table 8, the desktop computer consumes more than half of the energy used by all the appliances in the office. The approximate energy required in the office is 3135wh and the power develop by all the appliances is1855w.

From table 9, the desktop computer uses about half of the overall energy requirement of the department. The printer may be used for a longer period of time, that is, more than ½ hour, however, the increment it may cause in the energy usage could be compensated by the hours when it is not in use. The energy consumption in the office of the Faculty examiner is 2220Wh as seen in table 10 while the power developed by the appliances altogether is 2775W.

Table 9: Load analysis of Physics Department

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	2	65	6	130	780
2	Bulb	4	15	5	60	300
3	Laptop	5	65	4	325	1300
4	Printer	1	1200	1/2	1200	600
5	Desktop	2	240	3	480	1440
	Total				2195	4420

Table 10: load analysis of the faculty examiner office.

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power(W)	Total Energy(Wh)
1	Ceiling fan	1	65	6	65	780
2	Bulb	3	15	6	45	300
3	Laptop	1	65	4	65	1300
4	Printer	1	1200	½	1200	600
5	Desktop	-	-	-	-	1440
6	Photocopy machine	1	1400	½	1400	
	Total				2775	2220

Table 11: Other lightings and ceiling fans

S/N	Appliance	Quantity	Power Rating(W)	H.O.U	Total Power (W)	Total Energy (Wh)
1	Ceiling fan	2	65	6	130	780
2	Bulb	41	15	18	615	11070
	Total				745	11850

Table 11 depicts the load analysis of security bulbs and ceiling fans in the corridor of the Faculty of Science. A quick glance at the respective power requirements for the various offices including the total energy is captured in table 12.

Table 12: Summary of the load analysis for all the rooms and offices in the faculty building.

S/N	Table no	Total power (W)	Total energy (Wh)
1	Table 1	465	2940
2	Table 2	2815	4865
3	Table 3	510	2430
4	Table 4	550	2620
5	Table 5	3280	3645
6	Table 6	2605	4155
7	Table 7	3170	4180
8	Table 8	1855	3135
9	Table 9	2195	4420
10	Table 10	2775	2220
11	Table 11	745	11850
	Total	**20965**	**46460**

Inverter sizing estimation.
From equation (2)
$Iv_s = P_T + I_S$
Assuming 30% provision for starting current.

Therefore, size of inverter = 20965W × 1.30
=27254W
=27.254Kw ≈ 18×1514VA
Therefore, based on availability eighteen 1.5KVA, 24v inverter is recommended

Energy requirement E
From equation (1)
$E= P \times H + P_L = 46460Wh \times 1.25 = 58075Wh$
(1.25 is a factor that accounts for 25% loss in the system)
From the inverter specification, system voltage V_{sys} =24V.
The ampere-hour requirement Ah = energy requirement E / system voltage V_{sys}
=58075Wh / 24V
Ah =2419.80Ah
The charging current I_C = ampere-hour Ah / peak sunshine Sp
= 2419.80Ah / 8h
= 302.47A
Module sizing estimation.
From equation (7)
$M_{par} = I_C / I_{mp}$
$M_{par} = 302.47A / 7.14 = 42.39 \approx 42$ No
(7.14 is the specification for I_{mp} of the module selected; PV module selected is P_w = 125W, V_{mp} =17.46V, I_{mp} =7.14A, V_{oc} = 21.74V, I_{sc} =7.60A)
From equation (8)
$M_{ser} = V_{sys}/Vn$
= 24 / 12
= 2 No
Total number of modules $M_{tot} = M_{par} \times M_{ser}$
= 42 × 2
= 84 No
Therefore 84 number of 125W modules are required.

Charge controller sizing.
From equation (9)
$I_{cc} = M_P \times I_{sc} \times F_S$
= 42×7.60×1.25
=399A
Number of charge controller is 399A/40A
=9.975
=10No
(the factor 1.25 is to make provision of 25%)
Therefore, ten 24V, 40A Charge controllers are recommended.

Battery sizing.
Assume day of autonomy = 1
Depth of discharge, DOD = 75%
Battery storage capacity (B_{SC}) is given from equation (3) as

$$B_{SC} = (E \times D) / DOD$$

$$= (2419 \times 1) / 0.75$$
$$= 3226.40Ah$$

Number of battery in parallel (B_P) is given from the equation (4) as
$B_P = B_{SC} / B_C$
= 3226.40Ah / 200Ah
= 16.13
B_P = 16 No

Number of battery in series (B_{ser}) is given from the equation (5) as

$$B_{ser} = V/V_B = 24/12 = 2No$$

From equation (6) $B_{tot} = B_P \times B_{ser}$

$$= 16 \times 2 = 32\ No$$

Therefore, thirty-two 12V, 200Ah batteries are recommended.

The circuit diagram is shown in figure 1.

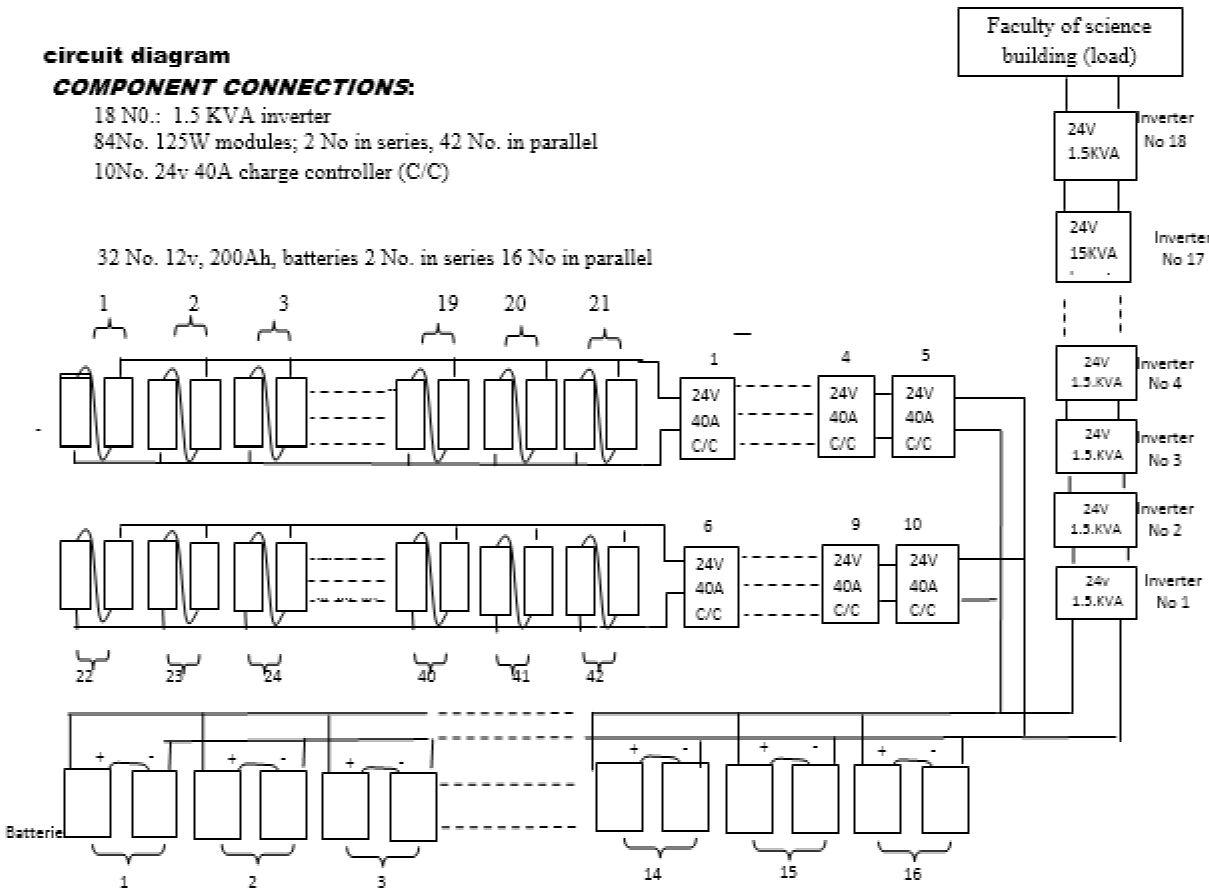

Figure 1: Circuit Diagram of the system components.

Discussion

There abound a lot of research work on renewable energy potential and resources available in Nigeria however very few focus on off-grid solar photovoltaic (PV) systems design while a lot focus on techno-economic analysis.

This paper emphasizes a design model methodology using a University campus as a case study where electricity is required round the clock for various activities.

Manjor *et al*. (2021) designed an alternative off-grid solar PV system for the Rivers State University administrative building. The result showed that a 75KVA 3 phase Inverter, 20 of 400W modules and 360/100A solar charge controllers are needed for the 60KW selective load. Esan *et al*. (2017) designed a prototype for the solar energy system of a two-bedroom apartment in Landmark University, Kwara State. The total wattage was about 9.8 kW. The solar PV energy needed was 17 kWh. The result showed 20 of 300 watts modules, 48 V inverter of between 16 kVA and 20 kVA, 4 of 12V 200 Ah

batteries and 110 A charge controllers are required to power the load.
In similar research, Bitrus *et al*. (2020) designed a model for a two-bedroom flat with total consumption capacity of 1015 W and total PV energy needed as 10.16 kWh. 6 of 200 W PV modules, 2.5 kVA inverter, 4 of 12 V 220 Ah batteries and 60 A charge controller were used for the design. A technical analysis carried out by Makinde *et al*. (2021) for a total daily load of 9.57 kWh showed that a 14 of 250 W PV modules, 36 of 12 V 200 Ah battery capacity, 2 of 5 kVA inverters and 20 A 220 V charge controller are enough design parameters estimated for the stand-alone PV system for the considered site. All these studies confirm the fact that solar PV system is cost-effective and a more sustainable alternative compared to conventional electricity sources.

Conclusion

There is a need to embrace utility of solar power for supplying of electricity in the University, particularly all the faculty buildings. This is to ensure non-interruption of the power as it may inconvenience both staff and students moreover hinder the progress of some crucial pro-academic activities. From our design, 84 of 125W modules, 10 of 24V, 40A charge controllers, 32 of 12V, 200Ah batteries and 18 of 1.5KVA inverters will be needed to construct the solar farm for the Faculty which will solve the issue of interrupted power outages in the building. The implication of the research will therefore help efficient deployment of a solar farm that will solve the basic energy need of the faculty building. The model can be used as a template for implementation to other faculty buildings and the University at large.

References

Akinosun, G. (2017). Solar energy; Nigeria best shot at eradicating its electricity problem. Retrieved from http://vanguargngr.com

Anyakoha M.W. (2011). *New School Physics for Senior Secondary School* (4th ED) African first publisher, Onitsha, Nigeria

Ayodeji,O.D. (2017). "National power grid: a blessing or course" retrieved from http://thecable.ng/fashola-2m-nigerians-benefitting-solar-products.

Bitrus I., Abba H. and Onwuasoanya N. C. (2020) Design analysis of a typical off-grid solar power system and the need for adequate maintenance: A case study of a two-bedroom flat apartment. *Iconic Research and Engineering Journals*. 4(2): 71-77.

Esan A.B. and Egbune D. (2017). Estimating the solar home system sizing for rural residential apartments using a panel tilt angle of 82 degrees: Ilorin, Kwara State as case study. *Electrical and Computer Engineering.* 1(3): 90-96.

Joshi, D.R. (2014). *Engineering Physics*, Mc GrawHill Education, (india) private limited.

Kristen H. and James C (2016). Components for your Solar Panel (Photovoltaic) System Retrieved from file\\\C:store\charge-controller\solar-charge-controllers-c892

Makinde K.A., Adewuyi O.B., Amole A.O. and Adeaga O.A. (2021). Design of grid-connected and stand-alone photovoltaic systems for residential energy usage: A technical analysis. *Journal of Energy Research and Reviews*. 8(1): 34-50.

Manjor I.F., Idoniboyeobu D.C. and Braide S.L. (2021). Development of alternative power supply for Rivers State University administrative building using the solar-powered system. *International Journal of Innovative Scientific & Engineering Technologies Research.* 9(3): 27-36.

Morais L. (2018). Renewables meet 100% of Portugal power demand for nearly three days. Retrieved from http://renewablesnow.com/news/renewables-meet-100-of-portugals-power-demand-for-nearly-3-days-605129

Nidhi, A. (2013). "Component of solar PV system". Retrieved from https://alternative-energy-tutorials.com

Ohakwere-Eze M.C (2015). The growth and Characterization of Copper Sulphide thin Film using CBD Technique. *Journal of Materials Science and Engineering*. B 5(3-4): 181-186.

Okafor P. (2017). Nigeria's first Solar Plant was inaugurated in the University of Ibadan. Retrieved from https;//www.vanguardngr.com/2016/10/university-Ibadan-gets-10mw-ngep-solar-plant/

Okechukwu, N. (2016). "Kaduna communities record two years uninterrupted power supply" Retrieved from https://puncng.com/kaduna-communities-record-two-yeaes-uninterrupted-power-supply

Onsen, A. (2016). History of solar energy. Retrieved from https://www.onsenaquecedoresjc.com

Piyush, S. (2018). "Solar PV system component" Retrieved from https://www.solaretribe.com/blog/solar-system-component

Richardson L. (2018). The history of solar energy, Retrieved from https://news.energysage.com

Sambo S.A. (2016). sustainable power supply in Nigeria: the need for expansion of the energy mix; maiden convocation lecture delivered at Federal University, Kashere.

Swati G. and Rahul G. (2013). "Solar panel image" Retrieved from https://www.industrybuying.com

Udeme A. and Prince O. (2017). "Nigeria: Govt, States, Others Invest $20bn in New 20 Solar Projects" 19 December 2017, Vanguard, Nigeria.

Xiamen N. (2013). "Solar PV system mounting equipment" Retrieved from https://www.solargroundmountsystem.com