Design of a Stand-Alone Photovoltaic Energy System for Small-Scale Business Outlets (Case Study of Arogbo Community in Ondo State)

A. O. Akinola [a*], M. D. Ephenus [a], J. F. Eiche [b], A. Akinsade [b] and A. B. Osasona [a]

[a] *Department of Mechanical Engineering, The Federal University of Technology, Akure, Nigeria.*
[b] *Department of Mechanical Engineering, Olusegun Agagu University of Science & Technology, Okitipupa, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

This paper designed a stand-alone photovoltaic energy system for small-scale business outlets in rural areas, using Arogbo Community in Ese-Odo Local Government Area of Ondo State, Nigeria as a case study. Structured questionnaires were administered to 150 business outlets for energy audit. Total energy estimate and consumption for 8 hours daily operation were estimated from obtained information. Total energy demand of the outlets based on their appliances used per day with power factor of 0.8 and 15% tolerance for a maximum load of 355.228 kW was 1,894.844 kWh. The specific energy required for a typical outlet (Barbing Salon, Computer Centre and Hairdressing Shop) were (0.938, 9.04 and 10.87) kWh, and their photovoltaic equivalence were estimated as (1.266, 12.211 and 14.67) kWh respectively. The solar components for the outlets were estimated as (0.317, 3.053 and 3.66) kW solar modules on installation areas of (3, 28.4 and 34) m^2. Inverter ratings of (0.22, 4 and 6) kVA were selected for the respective outlets. (1, 4, and 4) numbers of 12 V deep cycle batteries of (100, 150 and 150) AH were selected. Electricity generator capacities selected were (1, 4 and 6) kVA respectively.

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Corresponding author: E-mail: akinteche@yahoo.com;

1. INTRODUCTION

Energy is a central cross-sectional issue that affects all human activities, either directly or indirectly. It plays an essential role in the overall frame work of developmental planning and economic growth of any nation. Modern economy ways of life are almost impossible without reliable, constant and affordable supplies of energy [1]. Access to energy is fundamental for socio-economic development and poverty alleviation [2]. People in developing countries have extremely low access to energy, and the developed countries consume far more energy than the developing countries, suggesting that access to energy is the dividing line between the developed and the developing countries of the world [3].

The challenges faced by Nigerian government are how to reach out to the rural communities that do not have access to electricity and modern energy services despite the large energy potentials in Nigeria. Most of the rural areas lack reliable supply of electricity as a result of low generation and distribution of energy. These areas remain underdeveloped and backward in business, because, some of the artisans and small business owners find it difficult to run their businesses as a result of no electricity or high cost of electricity billing and environmental factors related to the distance from existing utility grid. As a result, most houses and small-scale business owners obtained their electricity from petrol- and diesel-powered generators that have adverse effect on the ecosystem. This dependence on generators caused a large consumption of fuel of poor quality, which caused a severe damage to the air quality and environment [4].

The environmental risks associated with the use of fossil fuels to power generators and vehicles in Nigeria have caused a great concern for Nigerians because it leads to release of greenhouse gases which resulted in global warming. Also, the noise from generators causes noise pollution and this affects the wellbeing of the rural users [5]. Asides the environmental issues, the financial implication for running them every day is very huge and this make researchers to consider renewable energy which is clean, reliable, affordable and environmentally friendly. According to [6], Nigeria has an installed generating capacity of 12 MW but with a generating capacity of 4 MW and as a result of this poor energy supply prompted people to divert into the use of an alternative means of energy supply.

Renewable energy sources such as solar energy remain the most viable option to alleviate the problems of electricity generation from fossil-fueled power station since it is clean and environmentally friendly. It is the alternative power source that would overcome the fears of running out of fossil fuel [7]. Nigeria is blessed with abundance of renewable energy potentials such as wind, biomass, geothermal etc., but the country is still facing an energy crisis, which has a major impact on the ability to reduce poverty and promote economic growth. Renewable energy resources transform the passive energy to a clean active energy used to generate electric power with no emission these include photovoltaic (PV) system being a most popular renewable energy resource since electricity generation by solar energy does not need fuel, the costs of maintenance is low, produces no pollution and noise [5].

The steady generation of alternative energy to reduce cost of running small scale businesses with petrol generator in rural areas is determined by the potential availability of renewable energy resources. According to [8], some countries have successfully utilized grid connected solar energy to produce electricity for residential homes, small scale businesses, workshop and many more. Researches have shown that more efforts have been made to combine the electricity generated by the solar with other sources to build hybrid power system with about 90% of the required power supplied by renewable energy sources [9,10] analyzed the potential implementation of hybrid photovoltaic (PV)/wind turbine/diesel system in Southern city of Malaysia, where seven different system configurations were studied. Also, [11] investigated the potential operation of hybrid energy system in the Northern city in Africa in which several system configurations with and without battery storage elements were studied. [2], developed off-grid hybrid energy system for residential buildings in rural areas. In their study, three different types of accommodations (three-bedroom Luxury, three-bedroom Convenience and room with parlour) were evaluated for energy requirements. These were estimated to be 10.015kWh, 3.216 kWh and 1.736 kWh respectively and their

photovoltaic (PV) energy system capacities were estimated to be 13.53 k Wh (16.91 kVA), 4.342 kWh (5 kVA) and 2.344 kWh (2.93 kVA) with power factor of 0.8.

The photovoltaic (PV) systems offer consumers ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems consist of photovoltaic cells that convert light energy from the sun directly to electricity [12,13]. A standalone PV system generates electricity during the daylight to supply the demand and charge the batteries while at night and cloudy days; it depends on the battery bank to supply the demand load. The PV panels and batteries generate DC power and the inverter converts it to AC power in order to supply the load. A typical Standalone PV system is shown in Fig. 1. Many researchers in the field of renewable energy have investigated the design, operation, optimization and cost analysis of a Stand-alone PV system for rural household electrification. [14], presented the design of a stand-alone PV system for a typical residential building in Bauchi, Nigeria based on medium energy consumption. [5], designed a 21.12 kWp stand-alone PV system to feed three departmental laboratories loads in AL-Nabrain University, Baghdad to ensure power continuity. Also, in the work of [15], a stand-alone PV system was designed as a power source for an ozone monitor laboratory at Anyigba, North Cenral, Nigeria. Photovoltaic/wind-based hybrid power system connected to a common bus with battery storage and conventional backup source to supply 2 kW telecommunication load was proposed for use in Malaysia [16].

Although, photovoltaic system has the disadvantage of high initial cost of procurement of components such as batteries, pv arrays, inverters and controller. However, it becomes cheaper on the long run as it attracts very low maintenance cost [5,7]

This study aimed at designing a stand-alone PV system to generate electricity for small scale business outlets in a rural area at affordable prices.

2. MATERIALS AND METHODS

2.1 Study Area

The area under study in this paper is Arogbo Community located in Ese-Odo Local Government Area of Ondo State in the South-Western part of Nigeria. The geographical location of the community is shown in Fig. 2. It is on Latitude 6.26^o North and Longitude 4.9967^o East with elevation of 5 m. It falls under the tropical climate region with rainy season between April and October and dry season between November and March. Arogbo Community has a population of 13,857 as recorded in the population census conducted in the year 2006 [18].

2.2 Research Questionnaire

In order to determine the total energy demand of the study area, a well-structured questionnaire was distributed and administered to about 150 small scale business outlets (barbing salon, computer service shop and hairdressing shop) to obtain information on the energy consumption patterns of their businesses based on the number of appliances used per day. Responses from the questionnaire were used to determine the energy audit of the area.
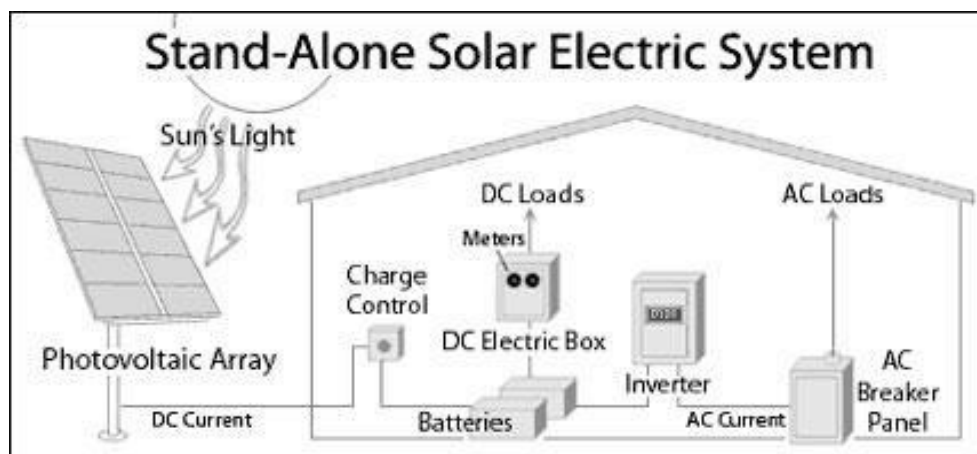

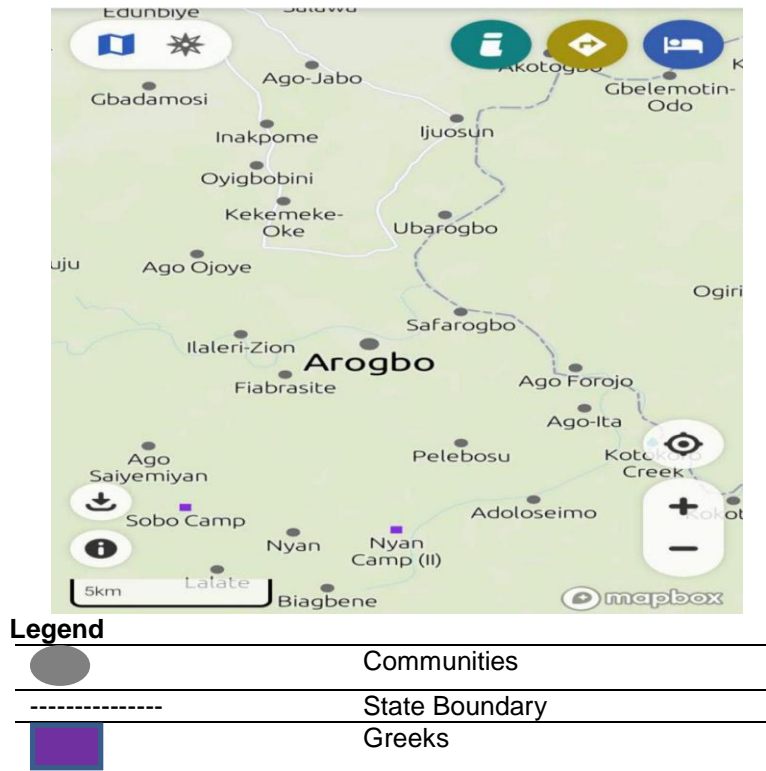**Fig. 1. A Standalone PV System [17]**

Legend

⬭	Communities
---------------	State Boundary
⬛	Greeks

Fig. 2. Google Map showing arogbo community [2]

2.3 Methods

2.3.1 Energy demand of the study area

Arogbo community is relatively sun-rich region with an annual solar irradiation of about 2190 kWh/m^2/year and with average temperature of 27°C. The average sunshine hour per day is 6 hours since the sunshine hours in the study area is between 3-9 hours per day. The energy demand was estimated based on the number of appliances for each business, power rating of the appliances and the time of usage of each appliance as obtained from the research questionnaire administered. Standard equations were used in determining the various energy parameters as discussed in [2].

2.3.2 PV energy sizing

a) PV energy required by each appliances

The amount of energy needed by the photovoltaic PV system for each appliance in each business outlet was evaluated using Equation 1

$$P_A = P_T \times H_D \tag{1}$$

where:

P_A is the amount of energy needed by each appliance per day in Watt-hour, P_T is the total power consumption of each of the appliances in Watts (W) and H_D is the average number of hours used per day by each of the appliances

b) Total PV energy required

In the design of PV system for any facilities, losses due to dirts, heat dissipation, resistance in the wire, inverter losses, batteries and PV module losses must be accounted for. The total energy required to power the study area and the losses accounted for were estimated using Equations 2 and 3 respectively [19].

$$S_P = \sum_{i=1}^{i=n}(P_A) \tag{2}$$

$$PL = PL_{PV} + PL_H + PL_D + PL_W + PL_I + PL_B \tag{3}$$

where:

S_P is the total energy required to power the area under study, PL is the total power losses in the appliances, PL_{PV} is the power losses due to the PV modules, PL_H is the power losses due to heat dissipation, PL_D is the power losses due to dirt

and dust in the solar panel, PL_W is the power losses due to wiring and mismatch, PL_I is the inverter power losses and PL_B is the power loss in the battery system.

Therefore, the total PV energy (E_{TPV}) required by each of the appliances in the area was evaluated using Equation 4

$$E_{TPV} = S_P + PL \qquad (4)$$

c) Sizing of PV arrays system

The PV arrays needed for each of the small-scale businesses under study were estimated using Equation 5 [20]. For efficiency and effectiveness, the PV arrays should be positioned in the right tilt angle for maximum absorption of solar energy intensity.

$$S_{PV} = \frac{E_{TPV}}{R_H} \times \varepsilon_F \qquad (5)$$

where:

S_{PV} is the PV arrays size, E_{TPV} is the total PV energy required by each of the appliances, R_H is the average sunshine hour per day and ε_F is the efficiency factor assumed to be 1.5 in this study for effectiveness of the PV array system.

d) Number of PV panel required

In determine the total number of PV panel needed for the PV array system, the panel generation factor (PGF) is an important factor used to determine the total watt-peak for the PV panel capacity. The panel generation factor and the total watt-peak were determined using Equations 6 and 7 respectively.

$$PGF = S_{irrad} \times T_{CF-PV} \qquad (6)$$

$$P_{WP} = \frac{E_{TPV}}{PGF} \qquad (7)$$

where:

S_{irrad} is the average irradiation of the study area, T_{CF-PV} is the total correction factor for the PV arrays and P_{WP} is the total watt-peak for the PV panel capacity.

Then, the total number PV panel needed for the PV array system is given in Equation 8

$$N_P = \frac{P_{WP}}{P_{max}} \qquad (8)$$

where:

N_P is the number of panels needed for the PV arrays; and P_{max} is the rated maximum power of the solar panel.

e) Sizing of the inverter system

The sizing of the inverter was done based on the size of the PV array according to Equation (9). An additional power surplus of 20-30% is added to the S_{PV} while sizing the inverter system so as to prevent from working below the rated efficiency.

$$S_{INV} = \frac{R_P}{P_F} \qquad (9)$$

where:

S_{INV} is the system inverter, R_P is the real power (R_P is equal to 1.3 of total wattage of all the appliance) and P_F is the power factor (power factor of 0.8 is adopted in this study for efficiency of the system).

The micro-controller selected for this design system was based on the nominal voltage of the PV array. It is Multi Point Power Tracking Micro-controller (MPPTM) with the capability to automatically adjust the system voltage such that the PV arrays operates at their maximum power point and also deliver adequate power to charge the battery at little and appropriate time [21].

f) Sizing of the generator and battery of the system

The capacity of the battery used was determined using Equation (10) and the battery load in kW was given in Equation (11). The generator size (G_{SIZ}) was determined based on the total load (Loads of all appliance + battery loads) using Equation (12).

$$B_{CAP} = \frac{E_{TPV}}{B_{DD} \times N_V} \times N_D \qquad (10)$$

$$BL = (N_B \times V \times A) \times 10^{-3} \qquad (11)$$

$$G_{SIZ} = \frac{TL}{BL} \qquad (12)$$

where:-

B_{CAP} is the battery capacity, B_{DD} is the depth of discharge; N_D is the number of days used; N_V is the nominal voltage; BL is the battery load; N_B is the number of batteries; V is the battery voltage;

A is the charging current of the battery and TL is the total load.

g) Sizing of the solar charger controller (S_{SCC})

The solar charger controller is rated in-line with the amperage and voltage capacities of the solar PV arrays and batteries. It was determined using Equation (13)

$$S_{SCC} = I_{SC} \times M_{par} \times SF \qquad (13)$$

where:

I_{SC} is the short circuit current of the PV panel; M_{par} is the modules arranged in parallel and SF is the safety factor.

3. RESULTS AND DISCUSSION

3.1 Arogbo Community Electrical Energy Demand

The total electrical energy demand of the study area based on the information on average power consumption of the appliances and average hours of usage is shown in Table 1. The total power rating of the appliances in all the business outlets covered were computed as 355.228 kW and the total energy demand all the outlets over a specified period of average hours per day was estimated to be 1894.844 kWh with a power factor of 0.8 and 15% tolerance of the maximum load [2].

3.2 Average Losses in the Design of the PV system

The average losses in the PV system designed occurred most at the battery and inverter as shown in Table 2. The least losses occurred from the wiring.

3.3 Typical Barbing Salon Shop Energy Demand

The total power and energy cosumption per day for all the eight appliances in the barbing salon shop considered is shown in Table 3. They were computed as 0.136 kW and 0.938 kWh respectively.

The stand-alone PV hybrid energy system for the barbing salon was designed based on the energy information on Table 3. It was established that a single barbing salon shop required at least one (1) solar panel rated 300 W at voltage rating of 24 V, one (1) battery of 100AH at 24 V, a 0.22kVA, a charge controller rated 12 A and a 0.47 kVA generator as shown in Table 4.

The schematic diagram of the Stan-alone PV system designed for the barbing salon shop in Arogbo community is shown in Fig. 3.

3.4 Typical Computer Centre Shop Energy Demand

The total power and energy cosumption per day for all the eleven appliances in the computer centre shop considered is shown in Table 5. They were computed as 2.035 kW and 9.045 kWh respectively.

Table 6 showed the summary of the analysis of the stand-alone PV system designed for a typical computer centre in Arogbo community. It was established from the analysis that a single computer centre required at least six (6) solar panels rated 500 W at voltage rating of 48 V each, four (4) batteries each being 150 AH at 12 V, a 4 kVA inverter, a charge controller rated 82 Amps, and a 4 kVA generator to generate electricity needed to power the appliances in the shop.

The schematic diagram of the designed stand-alone PV hybrid energy system for the computer Centre shop in Arogbo community is shown in Fig. 4.

3.5 Typical Hairdressing Salon Shop Energy Demand

The total power and energy cosumption per day for all the seven appliances in the hairdressing shop considered is shown in Table 7. They were computed as 3.49 kW and 10.87 kWh respectively. The summary of the analysis of the Stand-alone PV hybrid energy system designed based on the energy information on Table 7 for an hairdressing salon shop is shown on Table 8. It was established that it requires a minimum of seven (7) solar panels rated 500 W at voltage rating of 48 V each, four batteries each being 150AH at 12 V, a 6 kVA inverter, a charge controller rated 101 A and a 6 kVA generator.

The schematic diagram of the stand-alone PV hybrid energy system designed for a typical hairdressing salon shop in Arogbo Community is shown in Fig. 5.

Table 1. Energy demand for arogbo community

S/N	Facilities/Appliances (F/A) Captured	Total Quantity of each F/A	Number of Outlets	Average Power Rating (P_R) of F/A in (Watt)	Average Hour Usage per day h_D, (h)	Total power Rating of F/A. $P_A = P_R$ X Qty, in (Watt)	Power Need per Day. $P_D = P_A$ Xn (Wh)
1	T v LCD/LED/Plasma	60	60	40	8	2400	
	B/W & Coloured	90	90	85	8	7650	80400
2	DSTv	65	65	25	8	1625	130000
3	Startime	85	85	24	8	2040	16320
4	Air Conditioner	10	10	1010	3	10100	30300
5	Refrigerator	130	92	100	8	13000	104000
6	Deep Freezer	70	70	220	10	15400	154000
7	Sound System	150	150	95	10	14250	142500
8	Single LED Bulb	300	150	10	8	3000	24000
	40W Build	300	150	40	8	1200	9600
9	Ceiling Fan	200	150	75	8	15000	120000
10	Standing Fan	75	50	60	8	4500	28000
14	Electric Stove	27	18	1000	2	27000	54000
16	Security Light	400	150	10	11	4000	44000
17	Play Station Games	18	10	85	4	1530	6120
18	Phone Charger	300	150	5	5	1500	7500
19	Water Heater	38	25	1200	0.5	45600	22800
20	Transistor Radio	150	150	6	8	900	7200
21	Rechargeable Light	70	60	5	2	350	750
22	DVD Player	150	150	35	6	5250	31500
23	Document Printer	70	50	300	6	21000	126000
24	Photocopy Machine	120	50	630	6	75600	453600
25	Laptop	100	90	45	4	4500	18000
26	Laminating Machine	13	7	450	0.5	5850	2925
27	Document Scanner	68	54	35	2	2380	4760
28	Desktop PC	110	50	120	8	13200	105600
29	UPS	60	26	240	2	14400	28800
30	WIFI – Router	18	11	6	8	108	864
31	Hair Clipper	300	60	10	8	3000	24000

S/N	Facilities/Appliances (F/A) Captured	Total Quantity of each F/A	Number of Outlets	Average Power Rating (P_R) of F/A in (Watt)	Average Hour Usage per day h_D, (h)	Total power Rating of F/A. P_A= P_R X Qty, in (Watt)	Power Need per Day. $P_D=P_A$ Xn (Wh)
32	Barbing Tools Sterilizer	9	9	20	8	180	1440
133	Towel Heater	4	4	60	6	240	1440
34	Hair Diffuser	14	12	260	3	3640	10920
35	Hair Curling Iron	11	7	85	3	935	2805
36	Hair Hot Roller	8	8	300	3	2400	7200
37	Electric Hair Blower	8	6	1500	3	12000	36000
38	Electrical Hand Hair Dryer	15	12	1300	3	19500	58500
Total Energy Demand for 150 Business Outlets in Watts and Watts-hour						355,228	1,894,844
Total Energy Demand for150 Business Outlets in kW and kWh						355.228	1894.844
Total Number of Appliances Captured						3,396	

Table 2. Average losses in the system design

Losses	PL_{PV}	PL_H	PL_D	PL_W	PL_I	PL_B
Average values (%)	2	5	2	1	10	15
Total losses (%)	**35**					

Notes on Table 2
PL_{PV} is Power losses due to Photovoltaic Modules
PL_H is Power losses due to Heat Dissipation
PL_D is Power losses due to dirt
PL_W is Power losses due to Wiring
PL_I is Power losses due to Inverter
PL_B is Power losses due to Battery System

Table 3. Barbing salon energy demand

S/N	Facilities/Appliances (F/A) Captured	Total Quantity of each F/A	Average Power Rating (P_R) of F/A in (Watt)	Average Hour Usage per day h_D, (h)	Total power Rating of F/A. P_A= P_R X Qty, in (Watt)	Power Supply per Day. P_D=P_A X h_D, in (Wh)
1	Clipper	2	10	8	20	160
2	Tools Sterilizer	1	20	8	20	160
3	Single LED Bulb	3	10	7	30	210
4	Sanding Fan	1	60	6	60	360
5	Transistor Radio	1	6	8	6	48
Total Power Requirement in Watts and Watts-hour					136	938.0
Total Energy Requirement in kW and kWh					0.136	0.938
Total Number of Facilities/Appliances Considered					8	

Table 4. Summary of the design of stand-alone PV system for barbing salon shop

Sizing of the system	Equations	Values obtained
Power consumption per day	$S_{PV} = \frac{E_{TPV}}{RH} \times E_F S_P \quad = \sum_{j=1}^{j=5}(P_A)$	0.938 kWh
Solar PV Power requirement per day	$E_{TPV} = \sum_{j=1}^{j=5}(P_A) + PL$	1.266 kWh
Sizing of the PV Arrays	$S_{PV} = \frac{E_{TPV}}{RH} \times E_F$	0.317 kW
Arrays Area	$AM = S_{PV} \times 100ft^2$	3 m^2
Panel generation factor	$PGF = S_{irrad} \times T_{CF-PV}$ v	4.1
Total watt-peak of PV panel capacity needed	$P_{WP} = \frac{E_{TFV}}{PGF}$	309 Wp
Total number of PV panels needed	$P_{WP} = \frac{E_{TFV}}{PGF}$	1.06 ≈ 1 solar PV Module
Inverter sizing	$S_{INV} = \frac{R_F}{P_F}$	0.22 kVA
Sizing of Battery	$B_{CAP} = \frac{E_{TFV}}{B_{DD} \times N_V} \times N_D$	105AH (1 battery being a 100AH @ 24V)
Solar charge controller sizing	$S_{SCC} = I_{SC} \times M_{par} \times SF$	12 Amperes
Generator Sizing	$G_{SIZ} = \frac{TL}{BL}$	0.47 ≈ 1 kVA @ 0.8 PF

Table 5. Computer centre shop energy demand

S/N	Facilities/Appliances (F/A) Captured	Total Quantity of each F/A	Average Power Rating (P_R) of F/A in (Watt)	Average Hour Usage per day h_D (h)	Total power Rating of F/A. $P_A= P_R$ X Qty, in (Watt)	Power Supply per Day. $P_D=P_A$ X h_D, in (Wh)
1	Laptop	1	45	4	45	180
2	Printer	1	300	6	300	1800
3	Photocopy Machine	1	630	6	630	3780
4	Document Scanner	1	35	2	35	70
5	Desktop PC	2	120	8	240	1920
6	Laminating Machine	1	450	0.5	450	225
7	UPS	1	240	2	240	480
8	Single LED Bulb	2	10	7	20	140
9	Standing Fan	1	75	6	75	450
Total Power Requirement in Watts and Watts-hour					2035	9045
Total Energy Requirement in kW and kWh					2.035	9.045
Total Number of Facilities/Appliances Considered					11	

Table 6. Summary of the design analysis of stand-alone PV system for computer centre shop

Sizing of the system	Equations	Values obtained
Power consumption per day	$S_{PV} = \frac{E_{TPV}}{RH} \times E_F S_P = \sum_{j=1}^{j=5}(P_A)$	9.045 kWh
Solar PV Power requirement per day	$E_{TPV} = \sum_{j=1}^{j=5}(P_A) + PL$	12.211 kWh
Sizing of the PV Arrays	$S_{PV} = \frac{E_{TPV}}{RH} \times E_F$	3.053 kW
Arrays Area	$AM = S_{PV} \times 100ft^2$	28.4 m²
Panel generation factor	$PGF = S_{irrad} \times T_{CF-PV}$ ᵥ	4.1
Total watt-peak of PV panel capacity needed	$P_{WP} = \frac{E_{TPV}}{PGF}$	2978 Wp
Total number of PV panels needed	$P_{WP} = \frac{E_{TPV}}{PGF}$	5.96 ≈ 6 solar PV modules
Inverter sizing	$S_{INV} = \frac{R_F}{P_F}$	3.31 ≈ 4 kVA
Sizing of Battery	$B_{CAP} = \frac{E_{TPV}}{B_{DD} \times N_V} \times N_D$	508.8 AH (4 batteries each being 12V @ 150AH)
Solar charge controller sizing	$S_{SCC} = I_{SC} \times M_{par} \times SF$	81.525 ≈ 82 Amperes
Generator Sizing	$G_{SIZ} = \frac{TL}{BL}$	3.54 ≈ 4 kVA @ 0.8 PF

Table 7. Hairdresing salon shop energy demand

S/N	Facilities/ Appliances (F/A) Captured	Total Quantity of each F/A	Average Power Rating (P_R) of F/A in (Watt)	Average Hour Usage per day h_D, (h)	Total power Rating of F/A. $P_A = P_R$ X Qty, in (Watt)	Power Supply per Day. $P_D = P_A$ X h_D, in (Wh)
1	Tower Heater	1	60	6	60	360
2	Hair Diffuser	1	260	3	260	780
3	Hair Hot Roller	1	300	3	300	900
4	Standing Fan	1	60	6	60	360
5	Electric Hair Blower	1	1300	3	1300	3900
6	Electric Hair Dryer	1	1500	3	1500	4500
7	Single LED Bulb	1	10	7	10	70
Total Power Requirement in Watts and Watts-hour					3,490.0	10,870.0
Total Energy Requirement in kW and kWh					3.49	10.87
Total Number of Appliances Considered					7	

Table 8. Summary of the design analysis of stand-alone PV system for a hairdressing shop

| Sizing of the system	Equations	Values obtained
Power consumption per day	$S_{PV} = \frac{E_{TPV}}{RH} \times E_F S_P \quad = \sum_{j=1}^{j=5}(P_A)$	10.87 kWh
Solar PV Power requirement per day	$E_{TPV} = \sum_{j=1}^{j=5}(P_A) + PL$	14.67 kWh
Sizing of the PV Arrays	$S_{PV} = \frac{E_{TPV}}{RH} \times E_F$	3.66 kW
Arrays Area	$AM = S_{PV} \times 100ft^2$	34 m^2
Panel generation factor	$PGF = S_{irrad} \times T_{CF-PV}$ v	4.1
Total watt-peak of PV panel capacity needed	$P_{WP} = \frac{E_{TPV}}{PGF}$	3678 Wp
Total number of PV panels needed	$P_{WP} = \frac{E_{TPV}}{PGF}$	7.2 ≈ 7 solar PV modules
Inverter sizing	$S_{INV} = \frac{R_F}{P_F}$	5.67 ≈ 6 kVA
Sizing of Battery	$B_{CAP} = \frac{E_{TPV}}{B_{DD} \times N_V} \times N_D$	611AH (4 batteries each being 12 V @ 150AH)
Solar charge controller sizing	$S_{SCC} = I_{SC} \times M_{par} \times SF$	95.11 ≈ 95 Amperes
Generator Sizing	$G_{SIZ} = \frac{TL}{BL}$	6.1 ≈ 6 kVA @ 0.8 PF
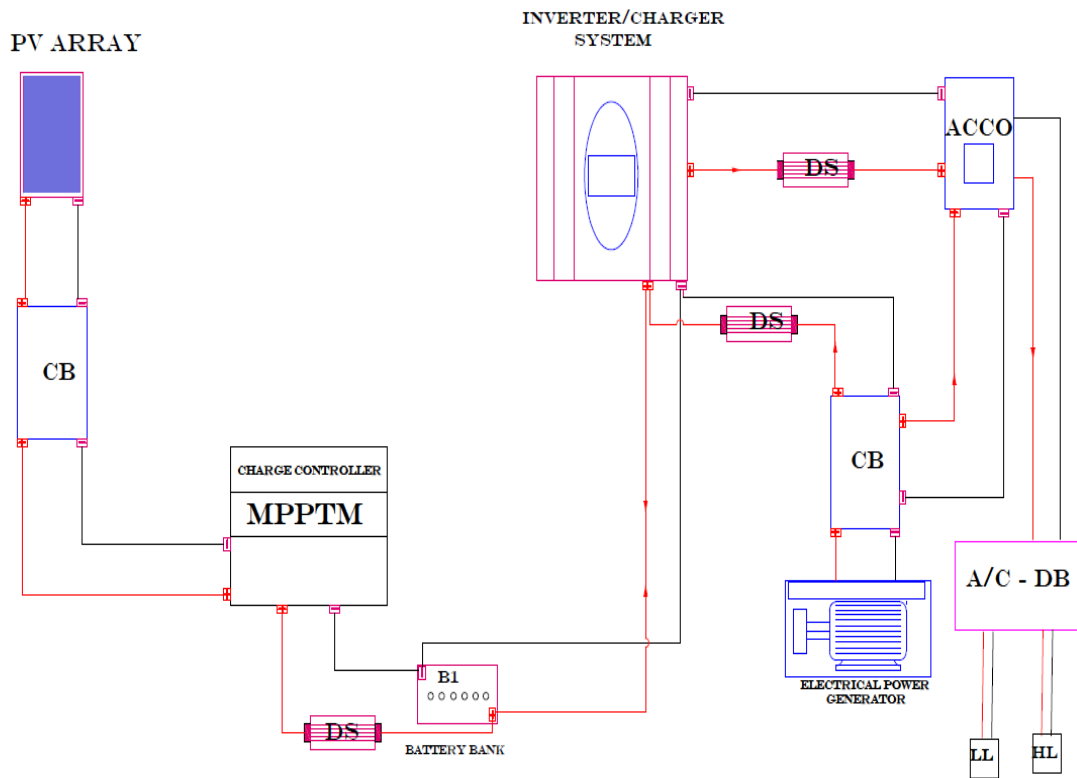
Fig. 3. A stand-alone PV hybrid energy system for a typical barbing salon
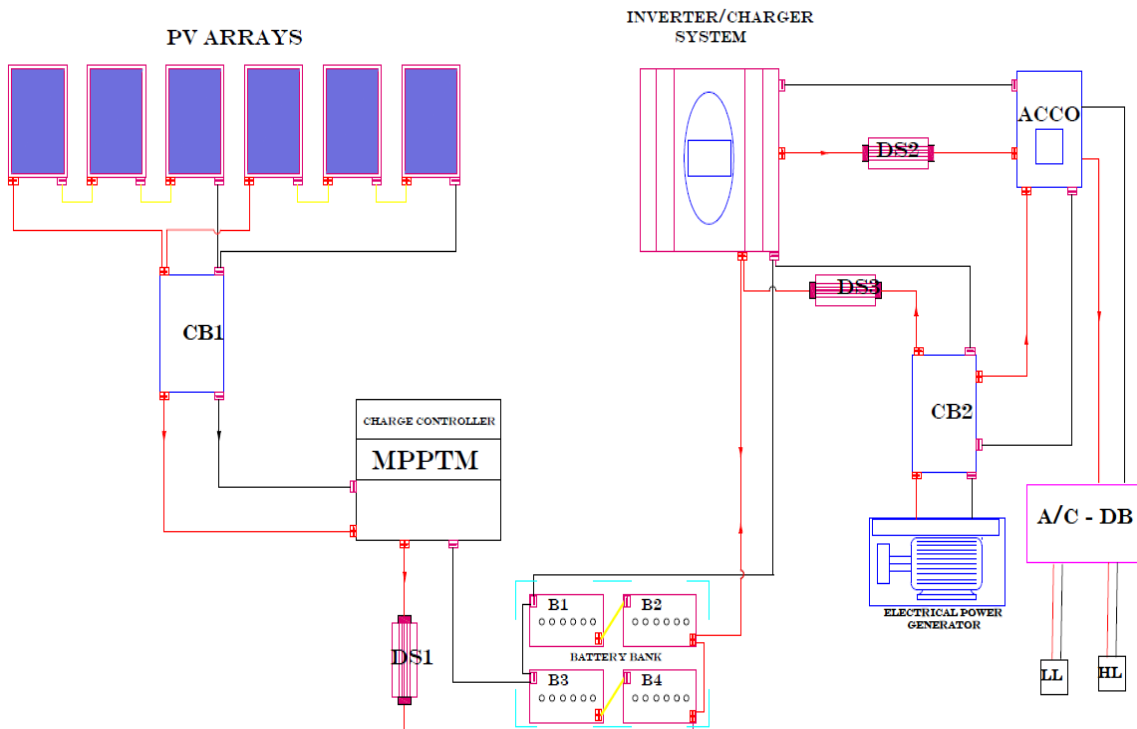
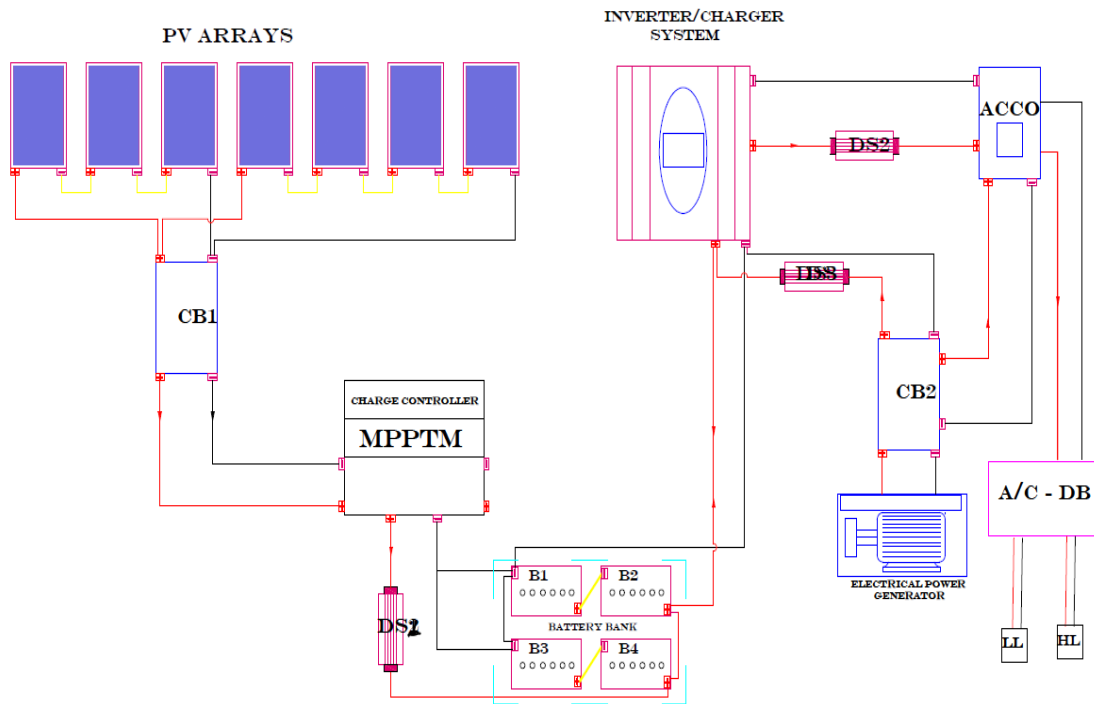**Fig. 4. A Stand-alone PV hybrid energy system for a typical computer centre**

Fig. 5. A Stand-alone PV hybrid energy system for a typical hairdressing shop

Table 9. Summary of the cost implication

S/No	Particular	Cost in naira (N)	Cost in dollar ($)
1	Barbing Salon Shop	354,500.00	866.25
2	Computer Centre Shop	1,972,500.00	4,931.25
3	Hairdressing Shop	2,494,000.00	6,235.00

3.6 Cost Implication

The cost of the various components designed and selected was based on the exchange rate of four hundred Nigeria Naira (N400.00) to one United State Dollar ($1.00). The summary of the estimated costs is shown on Table 9. This cost was based on unit purchasing of components and may vary at implementation the state of economy and bulk purchase.

On the basis of comparison, solar energy usage entails high initial cost, but cheaper on the long run. Solar is always available, while the conventional energy is not available at all in the study area. Though, the conventional energy use seemed less expensive than solar energy initially, however, the health, economic and environmental costs outweigh its value.

4. CONCLUSION

A stand-alone photovoltaic energy system has been designed for small-scale business outlets in rural area in this paper. The small-scale business outlets considered in the community are Barbing Salon, Computer Centre shop and hairdressing shops and energy audit was carried out for all the appliances in the business outlets. The following conclusions were drawn:

a. The total power rating for all the appliances collated was estimated to be 355.228 kW and total electrical energy demands for the outlets over a specified period of 8 hours per day with power factor of 0.8 and 15% tolerance was estimated as 1894.844 kWh

b. The total PV energy required for a typical Barbing Salon was estimated as 1.266 kWh (1.58 KVA) at a cost of ₦354,500.00

c. The total PV energy required for a typical Computer Centre was estimated as 12.211 kWh (15.26 KVA) at a cost of ₦1,972,500.00

d. The total PV energy required for a typical hairdressing salon shop was estimated as 14.67 kWh (18.33KVA) at a cost of ₦2,494,000.00

The study showed that electricity can be generated and supplied to rural areas through a Stand-alone photovoltaic energy system to power small-scale business outlets at affordable prices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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