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Web-based software application design for solar PV system sizing

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ABSTRACT

The solar photovoltaic (PV) energy source systems generally rely on the availability of sunlight, its duration, and the capacity of storage devices if it is not a grid-tie system. The components of the PV sources come in different sizes and capacities, depending on the various applications and available products in the market. Therefore, sizing of PV components becomes important to the functionality and reliability of solar PV sources. This work is aimed at the development of a web-based software application designed for sizing the capacity of solar PV source components that meet required energy demand. A description of photovoltaic system components, available types, and sizing techniques are discussed. Parameter evaluation algorithms with flowcharts were developed for PV components. Consequently, web-based software was developed and simulated for a different case study. The results described the estimated load, average daily load, ratings of PV system components such as inverter, battery, solar panel, and charge controller. The cost estimates of each component, the total estimated cost of the project, and the specification of components' purchasing store are similarly presented. Thus, the developed application can be applied to size different ranges of microgrid systems meant for several applications.

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1. INTRODUCTION

Energy is one of the fundamental human needs in life along with food, shelter, and water. Even the equipment needs one form of energy or the other to function. With fossil fuel reserves depleting, it becomes necessary to identify the most economical among renewable energy resources which are capable of minimizing the dependency on fossil fuels. Solar energy is identified to fit into this class as renewable energy. Sun influences the earth's climate and weather through light and radiant from it [1], [2]. Solar energy is used as solar thermal as well as for photovoltaic energy conversion and causes no environmental defaults. Solar energy is reliable without the presence of carbon dioxide which complies with a global policy on atmospheric pollution. It has rapidly developed as a power generation technique and competes with fossil fuels. In the past, developing countries generally rely on fossil fuels. Because the process does not involve any chemical decomposition and therefore no chemical emissions surfaced, solar energy conversion is termed a more environmentally friendly energy source. The continous over-dependence of these fossil fuels call for solar power technologies to evolve and thus create alternative energy sources. The evolution of solar energy increase competition thereby reducing generation cost [3], [4].

An environmental impact of solar energy is in its association in producing materials such as silicon, germanium, and phosphorus which made up the photovoltaic cells. These materials are purified with energy using chemical compounds like cyanide and sulfuric acids [5], [6]. The pollution resulting from solar cell production is managed at a production facility. But, the pollution in production sites considered very large is hazardous and as such may not be allowed into the environment [7], [8].

Methods available in determining the appropriate location for the conversion of solar power to utility energy are peak daily power on a horizontal surface (W/m^2), peak daily energy received by a horizontal surface (J/m^2), annual average incident power on a horizontal surface (W/m^2) and annual energy received by a horizontal surface (J/m^2) [5], [8]. Therefore, an installation that converts the incident solar power to thermal energy possesses the advantage of operating throughout the year with high production outputs. This implies that consideration of just a few bright days of the year is not valued. Consequently, the average power outputs per annum could be the parameter used in determining the potential of solar energy in that particular environment. Therefore, technological development has harnessed solar energy categories that include solar thermal and solar photovoltaic (PV) systems [5], [6].

Nowadays, renewables energy has become an option in the power sector in most parts of the world. In 2018, more than ninety countries had their renewable power capacity installed greater than 1 GW and about thirty countries had their own greater than 10 GW. This implies that renewables now account for about one-third of global power capacity. Research has therefore shown that technologies of renewable energy have been proven reliable and additionally provided the lowest-cost of power generation options. The day–to–day improvement in advanced technology for renewable energy resources such as PV systems, necessitates cost-effectiveness in the implementation of PV systems [5], [8].

Nigeria is rich in solar energy and possesses annual average daily sunshine of 6.5 hours. Four and Nine hours of sunshine are reportedly documented for coastal and northern areas of the country respectively. In the same development, 3.5 and 7 kWh/m2 solar radiation per day are found in the Southern and Northern parts of Nigeria. With the right technology used for determining solar radiation, nearly every location is good for solar energy generation [3].

In recent times, rural electrification has taken the turn of installing the off-grid system using PV and batteries. Sizing these systems is a bit difficult because it involves matching unpredictable energy sources with undeterminable demands in attempting to provide at best reliability and costs [4]. The output of such an arrangement is also unpredictable and non-linear. When available energy is short, overcoming load demand requires the usage of energy storage like the battery, the ultra-capacitor, and pumped hydro storage (PHS). Thus, the combined efforts of the renewable energy source and energy storage facility negate the source fluctuations. The available methods of sizing components for PV systems includes; manual, probabilistic, iterative, graphic construction, analytical/numerical, artificial, hybrid and software. Consequently, this research work is aimed at optimizing the utilization of a renewable energy source and energy storage by Web-based software application design for solar photovoltaic (PV) system sizing. The sizing of PV systems helps in reducing investment costs for installing stand-alone photovoltaic systems (SAPS) without changing the reliability of the systems [9].

Recently, publication made by the Ministry of New and Renewable Energy (MNRE) and The Energy and Resources Institute (TERI) presented seven PV simulation software that are mostly used to carry out design for solar PV systems worldwide. These programs are as follows: Homer Pro, PV F-Chart, PVPlanner, PVsyst, RETscreen, system advisor model (SAM) and solar Pro. Experience has shown that these programs are all good in design and simulation of solar PV power systems.

2. RESEARCH METHOD

The solar PV system is designed to supply solar energy using the PV process. It is an arrangement of components such as a panel that absorbs and converts sunlight into electricity, an inverter that converts the output from direct current (DC) to alternating currents (AC), a battery bank that stores energy, mounting structures, cabling, and other accessories useable in setting-up a working system. Categories of PV systems include portable/small type, Top-roof mounted type and building-integrated type. However, the capacity ranges from lower kilowatts ratings to large power stations of megawatts ratings [10]. The components that make up a photovoltaic (PV) system are load, inverter, batteries, solar panels, charge controller, PV cables, and mounting structure.

2.1. Photovoltaic components

- Load estimation: AC loads are mostly used in households with few DC loads like energy-saving light bulbs. In sizing the PV system, load constitutes the most important factor to consider in order not to undersize or oversize the system. The alternating current load is divided by a factor called inverter efficiency (K), this is necessitated as a result of current changes from DC to AC. In similar studies, an inverter efficiency of 0.85 is often assumed [4]. To get the average daily load consumption of a household, in (1) to (3) are used [4], [6].

$$T_{ac}(A1) = \sum_{i=1}^{n} \frac{Li\ldots n\times N\times D\times H}{K\times 7} \qquad (1)$$

$$T_{dc}(A2) = \sum_{i=1}^{n} \frac{Li\ldots n\times N\times D\times H}{7} \qquad (2)$$

$$T_{total}(A3) = T_{ac} + T_{dc} \qquad (3)$$

Where; T_{total} (A3) is the average energy demand per day, $L_{i\ldots n}$ is the individual load Wattage, N is the number of individual loads, H is the number of usage hours per day, D is the number of usage days per week, T_{ac} is the average daily energy demand for AC loads, T_{dc} is the average daily energy demand for DC loads and K is the inverter efficiency.

T_{ac} is divided by inverter efficiency (K) and termed power adjustment factor since Ac loads are connected through the inverter where conversion of DC to AC takes place. This power adjustment factor (K) varies in different inverters but in this work, it is assumed to be 0.85. In the same way, the inverter efficiency of 1.0 will consequently be used for T_{dc} conversion to DC since DC loads are connected directly to the battery. However, T_{dc} remains the same value even after divided by a power adjustment factor of 1. T_{ac} and T_{dc} are finally divided by 7 to get the average usage of each load in a week.

- Inverter***:*** PV inverters have some special functions in adaptation with PV arrays and they include maximum power point tracking and anti-islanding protection. The three classes of solar inverters are: Inverters used in an isolated environment are called Stand-alone inverters; Grid-tie inverters are inverters that work in synchronism with the utility power supply; Intelligent hybrid inverters are modern and more advanced solar inverter systems. The main function of this solar inverter is for isolated consumption with the use of storage [11].

Inverters are either rated in KVA or VA. Solar inverter rating must be designed higher than the connected load by at least 25%, this can be illustrated using (4a) and (4b).

$$\text{Total Wattage (B1)} = \frac{Tac\ (A1)}{total\ hours\ of\ usage} \qquad (4a)$$

$$\text{Power in KVA (B2)} = \frac{total\ wattage}{power\ factor} \qquad (4b)$$

where,

$Power\ factor\ (PF) = 0.85$

$$Size\ of\ recommended\ inverter = Power\ in\ KVA\ (B2) + (Power\ in\ KVA\ (B2)\ x\ 0.30). \qquad (5)$$

KVA (B2) x 0.30 is the additional 30% load expansion. This additional load expansion however varies with the type and the selected PV system but in this research work, 30% is chosen.

$$Cost\ Estimation\ (B3) = Number\ of\ inverters\ required \times Cost\ per\ module \qquad (6)$$

- Batteries: Batteries are of different types depending on the areas of application. Batteries of PV systems during operation experienced frequent charging and discharging processes. Very commonly used batteries in PV applications are lead-acid batteries because of their deep discharge. Also, gel-type lead-acid batteries are for remote applications where a maintenance-free operation is required. Nickel-Cadmium or Ni-Metal hydride batteries are applicable in a portable system. The life span of the batteries ranges from 3 to 5 years. This lifespan depends on several parameters such as temperature, and charging/discharging cycles [12].

Depth of discharge (D.O.D) which signifies the percentage at which the battery capacity will be used while supplying power to the photovoltaic (PV) system, days of autonomy (D.O.A) which signifies the number of days without sunshine to charge the battery (the higher the D.O.A, the bigger the battery bank that would be needed. The capacity of chosen batteries that would be used as battery bank is also considered.

Losses in the battery bank are also considered. The factors above are considered in this study. In (7) to (14) are often used in sizing the battery bank for the photovoltaic [12].

$$\text{Average amp} - \text{hour demand per day (C1)} = \frac{average\ energy\ demand\ per\ day(A3)}{inverter\ voltage} \tag{7}$$

$$\text{Required battery capacity (C2)} = \frac{C1 \times D.O.A}{D.O.D \times 0.85} \tag{8}$$

$$\text{Accounts for system losses} = 0.85$$

$$\text{No. of batteries in parallel (C3)} = \frac{C2}{Amp - HourCapacityofSelectedBattery} \tag{9}$$

$$\text{No. of batteries in series (C4)} = \frac{InverterVoltage}{SelectedBatteryVoltage} \tag{10}$$

$$Total\ number\ of\ batteries\ (C5) = C3 \times C4 \tag{11}$$

$$Total\ battery\ amp - hour\ capacity\ (C6) = G$$

$$G = C3 \times Amp - hour\ capacity\ of\ selected\ battery \tag{12}$$

$$\text{Total battery kilo} - \text{watts hour capacity (C7)} = \frac{C6 \times NominalVoltage}{1000} \tag{13}$$

$$Cost\ Estimation\ (C8) = Total\ Number\ of\ Batteries \times Cost\ per\ Battery \tag{14}$$

- Solar cells: some cells are made of a single layer of light-absorbing material called single-junction, while other types are made of multiple layers referred to as multi – junctions which take multiple absorptions and charge - separation mechanism. Thus, solar cells are classified based on the generation and how they are made. The conventional cells are wafer-based and made up of crystalline silicon with materials that comprise polysilicon and monocrystalline silicon. Monocrystalline solar cells are cut at four sides to make cylindrical silicon wafers. Most recent solar cells are made from thin-film modern technologies. It is an emerging photovoltaic due to its developmental stages [13]. Therefore, in sizing an array of solar panels, the average solar irradiance and daily sunshine hour of your location are considered.

The (15) to (21) are used to determine the following parameters needed for array sizing: array output per day, energy output in a module per day, modules needed to meet energy requirement, modules needed per string, Strings in parallel, modules to purchase, rated array output.

$$\text{Photovoltaic module Capacity required (D1)} = \frac{A3 \times 1.3}{PGF \times P_{sh}} \tag{15}$$

where $A3$ represents the average energy demand per day; the energy lost in the system is specified at 1.3; P_{sh} is the peak sun hour and PGF is the panel generating factor.

$$PGF = SI\ x\ TCB$$

SI represents the solar irradiance; TCF represents the total correction factor. The total correction factor for solar panels=0.62

$$No.of\ modules\ needed\ to\ meet\ requirement\ (D2) = \frac{Required\ PV\ module\ Capacity}{Selected\ PV\ Module\ Wattage} \tag{16}$$

$$\text{No. of Modules req. per string (D3)} = \frac{Nominal\ Battery\ Voltage}{Selected\ PV\ Module\ power\ Voltage\ at\ STC} \tag{17}$$

$$No.of\ strings\ in\ parallel\ (D4) = \frac{C2}{Number\ of\ Module\ sperString} \tag{18}$$

$$Total\ No.of\ Modules\ needed\ (D5) = G1\ x\ G2 \tag{19}$$

where, $G1$ is the no. of Modules needed per string and $G2$ is the no. of strings in parallel.

$$Rated\ array\ output\ (D6) = Rated\ PV\ module\ output \times Total\ panels\ needed \tag{20}$$

$$Cost\ estimation\ (D7)\ =\ Total\ number\ of\ modules\ needed\ \times\ Cost\ per\ Module \quad (21)$$

However, it is important to note that in (16) and (19) gives the same results. Thus, either of the methods could be used to obtain the total modules to meet the load requirement.

- Solar charge controller: the controller prevents the batteries from overcharging by reading the battery level, and the moment the battery is on full reading. Paramount importance is charging the batteries to correct voltage level specifications which help preserve the life span and health of the batteries. However, there are charge controllers with certain characteristics that allow one to wire panels in such a way to achieve charging goals [14]. In (22) and (23) are used for the sizing of a charge controller.

$$Charge\ Controller\ Current\ Rating\ (E1)\ =\ Isc \times numberofmodules(D4) \times 1.25 \quad (22)$$

$$I_{sc}\ =\ PV\ module\ short\ circuit\ current$$

$$Considered, safety\ factor\ =\ 1.25$$

$$Charge\ controller\ voltage\ rating\ (E2) =\ Voc \times No\ ofmodules\ req.per\ string\ (D3) \quad (23)$$

$$V_{oc} =\ Open\ circuit\ voltage\ of\ PV\ module$$

- PV cables: The National Electric Code (NEC) Article 690.31 Section B states that photovoltaic systems are to be wired with “single-conductor cable type USE-2 or single conductor cable listed and labeled as photovoltaic (PV) wire” [15], [16]. Types of wire use vary in conductor material and insulation. Thus, two-conductor materials which are commonly used for both residential and commercial solar installations are copper and aluminum. The cable is usually manufactured as either a solid or stranded conductor. This size of cable is often recommended and used for larger sizes of solar PV. Stranded cables have slightly better conductivity than solid cables because of their extended cable surface [11], [16].
- Mounting structure*:* these are structures where panels are placed facing the sun at a specified angle. Four mounting structura l types are available and these include; Roof/Ground, top of the pole, side of the pole, and tracking mounts with each type having pros and cons. In the roof/ground mounting type, panels are placed either on the floor or top of the roof of the building using the PV system. Wires are laid between arrays and battery bank is considered typically small quantity. Such solar PV is common in rural lighting systems where an existing network of Poles is in place for solar installation attachment. Lastly is the track mount structures which are extremely effective because they can fully utilize the full hours of sunlight during the day [17].

2.2. Photovoltaic sizing methods

Sizing of components for PV systems is a very critical process to be able to satisfy load requirements. Also, sizing is important for the cost estimation of a PV system. There are different methods of sizing components for PV systems which are: manual, probabilistic, artificial, iterative, graphic construction, analytical, software, and hybrid methods [9], [18]. In artificial sizing, machines are expected to perform functions that are like functions that are characteristics of human thought. The development of algorithms such as genetic algorithm, and particle swarm optimization are tools for sizing results [19]-[21].

The analytic approach described the hybrid energy systems which use computational models. Therefore, it is a function of reliability indices since more than one system is involved. The processing time required in this method is quite less compared to previous methods discussed above. The software method uses software such as hybrid optimization of multiple energy resources (HOMER), Hybrid2, and improved hybrid optimization by genetic algorithm (iHOGA) to compute the design specifications. Conventionally, the hybrid method combines two techniques with sum up influence in generating optimal results to meet the specified objective [9], [18], [22], [23].

2.3. Methodology

In this research, the software method of sizing solar PV is used. It involves the development of algorithms, formulation of flowcharts, and web application with programming in different languages. This software includes hyper text machine language (HTML) which was used to create and structure the webpage, cascaded style sheet (CSS) was used for styling the webpage, JavaScript (JS) was used for performing the arithmetic functions, hypertext preprocessor (HP) was used for the backend structure, and my structured query language (MySQL) used for database is an open-source relational database management system that runs as a server providing multi-user access to a number of databases. However, five steps are followed accordingly in the overall algorithm of the web application with several equations used in each step as follows:

Step 1: Load estimation using (1) to (3)
Step 2: Inverter sizing using (4) to (6)
Step 3: Battery sizing using (7) to (14)
Step 4: Array sizing using (15) to (21)
Step 5: Charge controller sizing using (22) to (23)
While the flowchart of the general algorithm is shown in Figure 1.

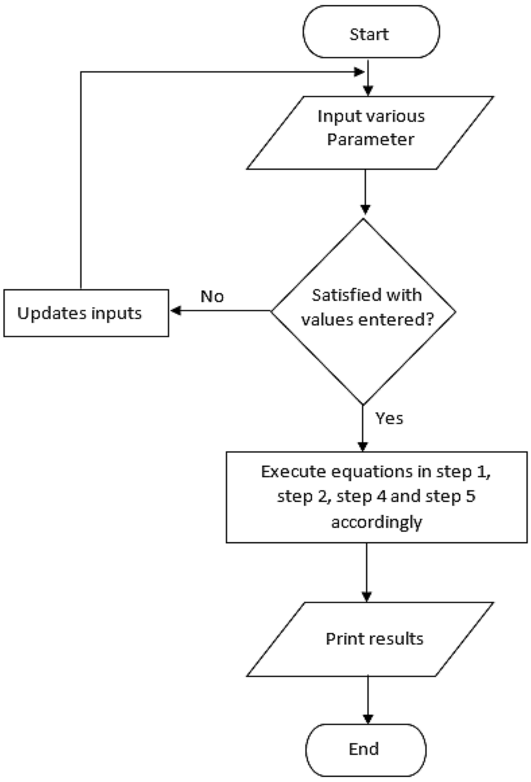

Figure 1. Flowchart of web-application algorithm

2.4. Description of solar sizing case study

A 2-Bedroom bungalow building located in Ilorin, Kwara State, Nigeria, was selected as a research case study. However, it’s important to note that the solar irradiance of the selected location is approximately 5.0 kWh/m2/day and the sunshine duration is approximately 6 hours/day [18]. Also, the peak sunshine hours are approximated as 6 hours. The procedures of sizing a solar PV system are as follows [18], [24], [25].

- Algorithms and formulated flowcharts

a. Load estimation: alternating current appliances in the house were itemized. Appliance operational designed wattage and number of this appliance available in the house determines the total wattage needed in the case study building. While this total wattage and the specified hours of equipment use per day determine the watts hour per day (Wh/day). The flowchart that illustrates the procedure is shown in Figure 2 while the results obtained from the software application are shown in Table 1.
b. Inverter specification: to size the inverter that would accommodate the total load of the household obtained in step 1 above, the flowchart of Figure 3 illustrates this. The software gave the results shown in Table 2. For this study, the tolerance value of the inverter was chosen to be 30.
c. Battery bank sizing: the flowchart in Figure 4 was followed in sizing the Battery bank capacity with the following values: Average energy demand per day=20 KWh, autonomy days=3 days, discharge depth=0.5, DC load=100 W, selected battery voltage=24 V, Amp-hour capacity of selected battery=200 Ah, inverter voltage=48 V and system loss of 0.85. The results are shown in Table 3.
d. Array sizing: array sizing was based on solar modules required for the PV system with the following values: Average energy demand per day=20 KWh, Peak sun hours=6 hours, solar irradiance=5 kWh/day, battery bus voltage 24 V, selected module power output=200 Watts, PV max power voltage=12 V. The results of the software application are shown in Table 4.

e. Charge controller sizing: module’s short circuit current=6.15 A and module’s open-circuit voltage=45.3. The results of the software application are shown in Table 5. Furthermore, depending on the type of inverter that is selected for the PV system, charge controller sizing may not be required because some inverters come with built-in charge controllers.

- Solar sizing results: Table 1 shows the results obtained from the algorithm application shown in Figure 2 for the load estimation of the PV system. The appliances in the house have been scheduled and estimated to give the total equipment wattage to be 3,575 Watts and the power consumption resulted in 20950 Watt-hour (20 KWh).

Therefore, using (4b), inverter size is calculated to be 5.6 KVA. Consequently, inverter size of the same calculated value or slightly greater than the calculated value and available to purchase is often recommended. Hence, 6 kVA inverter size is specified to be purchased.

Table 3 shows the average daily amp-hour consumption, the required capacity of the battery bank, number of batteries in parallel connection, number of batteries in series connection, the total battery needed, battery voltage, battery amperage capacity, brand, and cost of the battery bank. Table 4 shows the required array output, modules to meet the requirement, modules per string, number of parallel strings, the number of modules needed, Rated array output, and cost of modules. Table 5 shows the required current and voltage rating for a charge controller, it also displays the price of the recommended charge controller for this solar PV system. Therefore, total cost estimation of the photovoltaic (PV) system $= \# 2,298,619.00$. It is imperative to note that the cost of mounting structures, PV cables, and other accessories was not included.

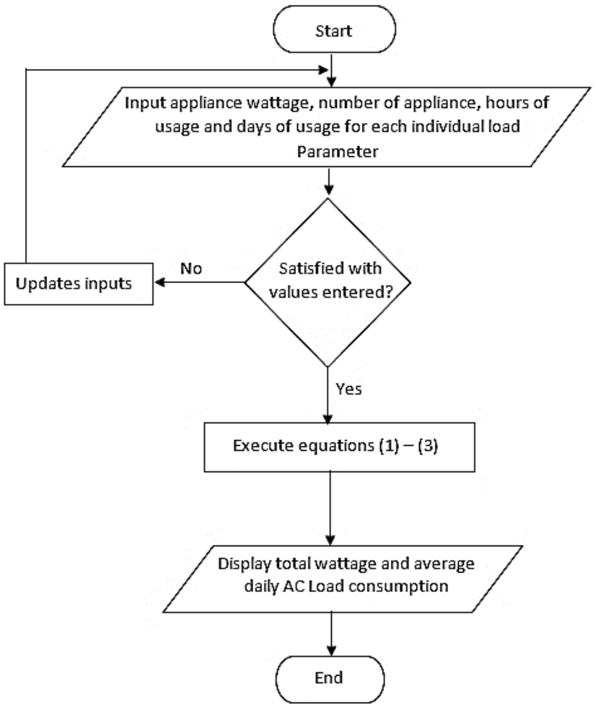

Figure 2. Load estimation algorithm

Table 1. Load estimation results

AC Load	Average watt (W)	Quantity	Total Watt (W)	Usage (hours per day) (Hours)	Usage (days per week) (Days)	Average Watts hour per day (Wh/day)
Ceiling Fan	75	4	300	24	7	7200
Desktop Computer	100	1	100	5	7	500
Laptop	60	5	300	7	7	2100
Phone Charger	5	6	30	5	7	150
Air Conditioner	1000	1	1000	4	7	4000
Washing Machine	500	1	500	1	7	500
Freezer	35	1	35	24	7	840
Refrigerator	180	1	180	24	7	4320
Iron	1100	1	1100	1	7	1100
22’’ LED TV	30	1	30	8	7	240
Total Watts			3,575 W	AC Average Daily Load		20,950 WH/day

Table 2. Shows the specified inverter information

Inverter Parameter	Rating
Store	Jumia Online Store
Brand	PRAG
Inverter Specification	6 KVA
Inverter Voltage	48 V
Cost Estimate of Inverter	#830, 000

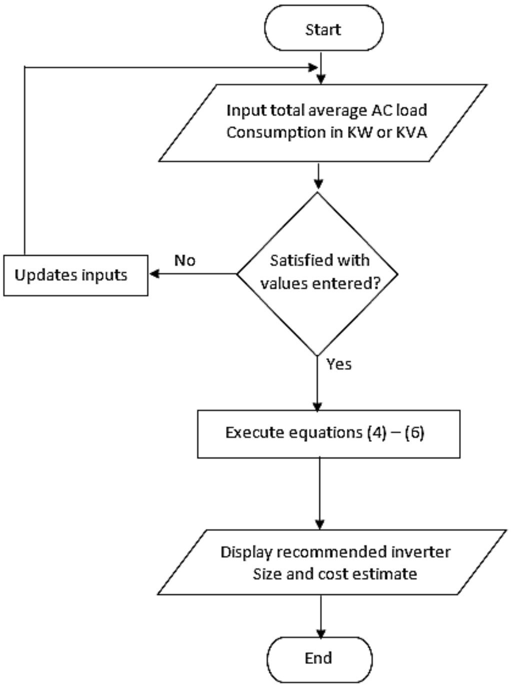

Figure 3. Inverter sizing algorithm

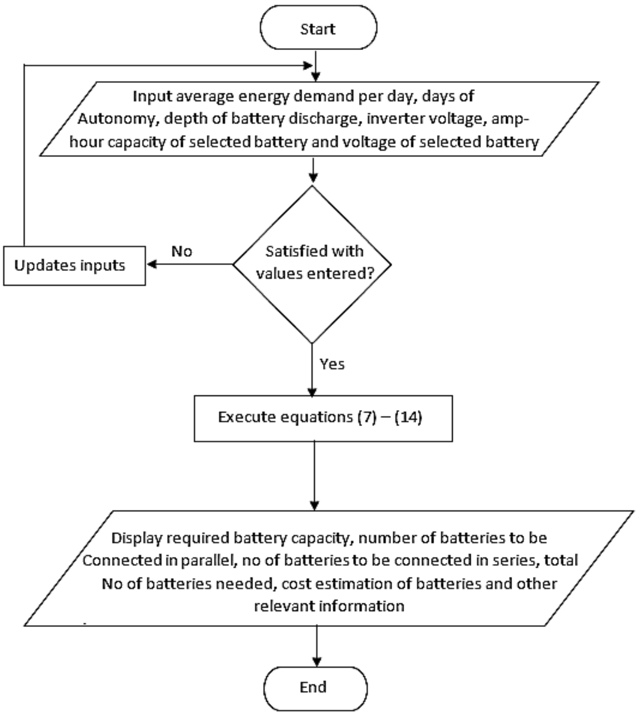

Figure 4. Battery bank sizing algorithm

Table 3. Battery specification results

Battery Parameters	Rating
Average Daily Amp-hour consumption	515 amps per hour
Required battery bank capacity	2062 amps per hour
No. of batteries in parallel connection	10
No. of batteries in series connection	2
Total Batteries Required	20
Battery Voltage	24 V
Battery Amp Capacity	200Ah
Brand	Mercury
Cost of 1No. 24V, 200Ah Mercury Battery	62,000.00
Therefore, the Cost of 20 No. 24V, 200Ah Mercury Batteries	#1, 240, 000

Table 4. Solar panel specification results

Array Parameters	Rating
Required PV Module Capacity (or Array Output)	1315 Watt-hour
No. of modules to meet the requirement	6
No. of Modules needed per string	2
No. of parallel strings	3
Rated Array Output	1200 W
Cost of 200W Solar Module	#29,400
Therefore, Cost Estimate of 6No Modules each of 200W	#176,400

Table 5. Charge controller parameters calculated and specifications

Charge Controller Parameters	Ratings
Calculated Current Rating	22.5A
Calculated Voltage Rating	47V
Specified Stores	Jumia Online Store
Specified Brand	Generic
Specified or Selected Controller Current Rating	30A
Specified or Selected Controller Voltage Rating	48V
Therefore, Cost of 48V, 30A Charge Controller Price	#52,219

3. RESULTS AND DISCUSSION

The wattage requirements of each category of household equipment were compiled using the equipment-rated watts as tabulated on Table 1. The table1 further shows that the total watts required for the case study building is 3,575 W while the total estimated daily load is obtained to be 20,950 watts an hour per day. From the case study building wattage estimate and the use of the appropriate equation, the required size of inverter rating was calculated to be 5.6 KVA which may not be directly available in the market. Thus, an Inverter rating of 6 kVA is the closest obtainable type and hence specified. At a glance, Table 2 shows the parameters that are associated with this specified inverter size rating of 6 kVA. Table 3 shows that a 6 kVA inverter, with a battery bank of 2062 Ampere-hour, and while table 4 shows that solar array capacity of 1.2 kW will be sufficient for a household having 4.4 kVA load with a tolerance of 30% additional load for 3 days of autonomy.

Likely constraints to this type of research include system losses that were already considered in the application and the tolerance for some components to comfortably accommodate any addition of load to the designed limit. The cost of various components may also vary from different stores across the country. Also, the weather in some areas may affect the sizing of the solar PV to be built. The results obtained from this research work are far more reliable than those seen in literature because of factors such as the concept of methodology, load demand, depth of discharge, the inclusion of the cost implications, and the software application built for this research work.

4. CONCLUSION

A lot of factors affect the sizing of a PV system. These factors include load requirements, days of autonomy, duration of a sunshine hour, solar irradiance of the location, and money availability to purchase a reliable PV system. With the rapid growth in renewable energy alternatives, the need for proper sizing guide is required in any photovoltaic (PV) system to avoid the possibility of oversizing and under-sizing. To achieve proper sizing of solar inverter, algorithms were developed, and the appropriate flowcharts were formulated. From these algorithms, a software program called python was developed and applied to the case study parameters. The results are presented and discussed. Thus, the research work has provided an easy and accessible means of sizing a stand-a-lone photovoltaic system (SAPS) in a developing country of which Nigeria is a good example. This research work has also made available a tool for solar contractors, homeowners, and business owners who want to make use of or build a photovoltaic (PV) system for various applications. Nigeria is blessed with abundant sunlight will have any photovoltaic (PV) system built reliably if proper sizing and proper maintenance schemes are put in place. This research work has demonstrated that software applications can be used to solve perennial domestic problems such as electrical lighting problems. Finally, the application built in this research can be used in sizing different ranges of microgrid stand-alone photovoltaic systems (SAPS).

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