International Journal of Science Academic Research
Vol. 04, Issue 09, pp.6264-6268, September, 2023
Available online at http://www.scienceijsar.com
ISSN: 2582-6425

Research Article

ENERGY EFFICIENCY MANAGEMENT DEMONSTRATED IN A [DC] ONE BEDROOM FLAT

Ibiam Nzogu Inya and *Arihilam, E. C.

Department of Electrical Electronic Engineering, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria

Received 24th July 2023; **Accepted** 29th August 2023; **Published online** 30th September 2023

Abstract

Clean energy is gaining grounds rapidly just when greenhouse gases and carbon emissions are immensely hurting our ecosystem. Nowadays, it has become common place to use solar power not only in commercial unit but also for residential purposes. Gladly enough, the unit cost of solar power installation has steadily dropped but, could even drop further if we have the capacity of setting up the installation which overall, can help keep the acquisition within budget. In this study, we present a practical approach to proper energy management on hoe to install a solar power unit in a one-bedroom apartment housing essential house-hold equipment. The set up comprises of the four basic solar power ingredients namely, solar panels, charge controllers, inverters, and a bank of batteries. Additionally, we included a circuit breaker, meter, MC4 connectors and fuses. Although there are smart solar panel calculators that could determine the choice of the components, the design method used in this application is to manually take the raw calculations based on load requirements. This method presents an ideal guide to installers who can either ill-afford the smart tool or are not familiar with its usage.

Keywords: Bank of Solar batteries, Charge Controllers, Inverters, MC4 Connectors, Smart Solar Panel Calculator.

INTRODUCTION

There is a growing body of literature [1] [2] that recognises the importance of solar energy utilization [3]. Potentially dwells on effective energy management using the solar power. One of the greatest challenges in solar energy usage is to first determine the size of the installation. In so doing, a review of the desired energy consumption habits and a complete aerial assessment of a given property is done to determine how many solar arrays could best fit in. Much uncertainty still exists on the correctness of individual installers relying completely on using the smart tools in determining most data for solar installations. This stems from the fact that there are no known standards yet available for solar power installation. Hence, in this paper we have attempted to give an account of each electrical load contributions to effective energy management in a home setting.

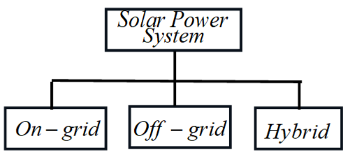

Figure 1 Types of Solar power system

The first section of this paper examines the various electrical loads followed by a brief overview of the criteria for the choices for the basic solar power components. Next is the step-by-step consideration of the components and the reasons for their choice in the design. Also considered are the mathematical implications leading to the choice of the components.

Choice for the Inverter

The rule of thumb in solar installation is an inverter whose capacity is around 20% higher than the largest output power. In the open market there are inverters with varying capacities such as 3.5Kva, 5Kva, 7.5kva, 10Kva, etc. Based on the calculation that will be explain later, 3.5Kva inverter with a tolerance of. (which is closest to the 20% specified) of the total household load was chosen. The inverter which converts the DC into the required AC comes in various power wattages and types including square waves, modified sinewave, and pure sine wave. Square waves are not compatible for all devices, while the output of modified sine wave is not suitable for certain applications, like a refrigerator. Pure-sine wave inverters, which is the type used in this project, is the best choice for most solar projects.

Choice and Number of PVC Solar Panel

Solar panels are usually of two kinds namely monocrystalline and polycrystalline solar panels. Both however are made from silicon raw material, but it is their arrangements in the panel that distinguishes them. From the appearance viewpoint, monocrystalline solar cells are circular, and the surface is not patterned, while the four corners of the polycrystalline cells are square, and the surface is like an ice flower. The monocrystalline solar panel are lined up with single silicon cells with abundant spaces for electron migration, unlike the multi-crystalline solar panel. Hence, the efficiency of the monocrystalline silicon panel is higher than that of polycrystalline panels. As a result of this a choice was made of the monocrystalline solar panel, though the price was a little higher. We went for 350 watts panel and to meet my energy design requirement, I decided for

$$= \frac{1400}{350} = 4 \text{ solar panels}$$

Choice of Solar Battery

A deep cycle battery can be described as a lead-acid battery that can regularly discharge when in use and then can be re-charged. One discharge half cycle plus one recharge half cycle

Corresponding Author:** ***Arihilam, E. C.
Department of Electrical Electronic Engineering, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria.

equal to one complete cycle. Deep cycle batteries are desired to deliver sustained power with low current drawn over extended period of time. This is contrary to starting batteries that can start engines, work as a voltage stabilizer, and run accessories when the energy is not functioning. In this design, care was taken not to keep the deep cycle battery in a low state of charge as this state will build up sulphation on the battery plates that will reduce the performance and cycle life of the battery. It is good practice to discharge a battery to no lower than 50% DOD (i.e., depth of discharge), with a maximum of 80%. In this project 4 12v/200Ah deep cycle was used. Solar batteries usually last 12.5 years [4] on the average, and since solar panels last at least 25 years, one would need 2 batteries for the lifetime of a solar panel. Without using the batteries, one would likely be using 50% of the electricity generated by the panel instead of 80`% with the battery [5]. Basically, using a higher voltage solar battery (e.g., 24v) enables much more solar power to be connected to a 20A solar charge controller. Traditionally, based on Ohm's law and power equation, higher power voltage enables more solar panels to be connected. This is according to the formular.

$$Power = voltage \times current$$

By way of recommendation 20A MPPT with a 12volts battery = 260 *Wrated*max *solar panel power.*

20A MPPT with 24Volt battery = 520 *Wrated*max *solar panel power.*

20A MPPT with 48V battery = 1040 *Wrated*max *solar panel power.*

It must be noted that oversizing the number of solar panels may be allowed by some designers to ensure an MPPT solar charger operates at the maximum output charging current, provided the maximum input voltage and current are not exceeded.

Choice of solar charge controller

A solar charge controller is basically a solar battery charger connected between the solar panels and the battery [6]. Its duty is principally to regulate the battery charging process and ensure the battery is charged correctly, or more importantly, not over-charged. Solar charge controllers are rated according to the maximum input voltage (V_{in}) and maximum charge current (I_c). These two ratings determine how many solar panels can be connected to the charge controller. In this design, the MPPT (maximum power point tracker) was used. The MPPT solar charge controller can be up to 30% more efficient compared with the PWM (pulse width modulation) type of charge controllers, depending on the battery and the operating voltage of the solar panel. As a general guide, the MPPT charge controller are used on all higher power systems, that is, when two or more solar panels are in series, or whenever the panel operating voltage is 8V or higher than the battery voltage [7]. To generate the most power, the MPPT sweeps through the panel voltage to find the sweet spot or the best combination of the voltage and current to produce the maximum power. The MPPT continually tracks and adjusts the panel voltage to generate the most power, no matter what the time of day or weather conditions. By this technology, the operating efficiency greatly increases, and the energy generated can be up to 30% more compared to a pulse width modulation type [8].

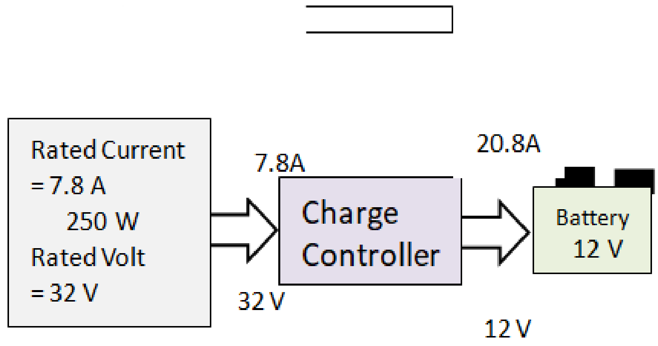

Figure 2. The MPPT solar charge controller connection

Design Method

Five sequential design methods were followed in this project.

Step 1 Sizing all the loads

In this step we noted all the home appliances used in the home and summed up the power consumption in the home.This included, television, lamps, fans, etc. Next, we added the time for which these appliances may run in a day. Also, we went through the specification chart in the household electric appliance to check their usage duration or run time and their rating. Then we calculated the $"Watt - hour"$ by multiplying the run time of any appliance with its power rating following this step for each electrical device, we then summed up the individual watt-hour numbers to get the grand total. For example,

Application	Power rating	Number of hrs usage	Watt-hr
Electricalfan	75 watts	6 hrs	450 Whr

In the apartment of our study, the user is presumed to have the following.

1. 1 washing machine
2. 1 TV
3. 1 decoder
4. 1 blender unit
5. 10 lighting points (LED
6. 2 PC
7. Ceiling fans
8. Mobile phones

Step 2 Solar Panel Selection

At this point, connections are made both in series and parallel. Series connections are made by connecting a device's positive terminal with another device's negative terminal. For a parallel connection, we connected one device's negative terminal with another device's negative terminal and so on. Again, the loses in the system, especially at the load end, were considered by considering the load subsystem efficiency [9]. This included loses in the battery, wiring and loses in the inverter as signals are converted from DC to AC. By this consideration, the system efficiency was generated.

From Table 1, Total power required per day = 1,565 watts. Also from Table 1, the total energy required per day = 5,855 watts.

Table 1. Aerial assessment of energy consumption per day in the property of our study

Load name	Power of load (w)	Number of loads	Total Power Rating (watt)	Operating hour	Total energy (Watt-hr)
Washing machine (LG	440	1	440	2	880
TV (LED	65	1	65	5	325
Decoder	60	1	60	5	300
Blender	500	1	500	1/2	250
Lamps (LED	10	10	100	10	1000
PCs (*hp*	65	2	130	4	1600
Fans	40	6	240	6	1440
Mobile phone	5	6	30	2	60
		Total power	1,565	Total energy	5,855 W-hr 5.855KW-hr

Therefore, the power required from solar panel (PV) is given by.

$$\frac{Total\ energy\ required\ from\ the\ panel\ (Whr}{Effective\ sunshine\ (hr)\ x\ System\ efficiecy\, \eta_s}$$

N/B in this design we use an annual average sunshine hrs in Nigeria of about 6.5hrs, (Coming from 3,5hrs in the south to 9.0hrs in the north). Hence,

$\eta_s = \eta_B \times \eta_1 \times \eta_{other-componenets}$ [10]

η_B = Battery efficiency (assume 85%

η_1 = Inverter efficiency (assume 95%

$\eta_{other-componenets}$ = other components (controller, cable, etc.) assume = (85%

Therefore, system efficiency = $0.85 \times 0.95 \times 0.85 = 0.68$.

$$\frac{5855}{6.5 \times 0.68}$$

Power required from solar panel $= \frac{5855}{4.42}$

$$= 1324.66$$

□ 1400

In this design, we used a 350 W solar panels and determined the number used in this manner.

Number of panels required = $\frac{Power\ required\ from\ panel\ (Wh}{Output\ power\ of\ solar\ panels}$[11]

$$= \frac{1400}{350} = 4 =$$ 4 Panels

Step 3 Fixing of Solar Panel

First, the best sunspot, i.e., where there are no shadows and obstructions for the panels are determined. Second, the tilt of the mounting stand (either on the roof top or o ground) should be equal to the latitude angle of the location facing the sun. Next, we followed the small junction box at the back of the solar panel to determine the polarity (+ve and -ve) of our connections. Following the above, we aligned the junction with the external wires using the black and red wires for the negative and the positive terminal connections, respectively.

Step4 Selection and Charging of Battery

A battery in the solar energy network helps to provide electricity when the sun goes down. A lead acid battery or a lithium battery stores solar power generated during the daytime and discharges it at night. This is possible when the optimum battery storage capacity has been selected. In addition, a power controller, which sits between the solar panel and the battery is provided to monitor the charging ability of the battery. Charge controllers come with a small LED light that announces the charging state of the battery, and it adjusts the power that flows into the battery [12].

To determine the capacity of the battery, needed in this design, the following calculations were made.

Total power required per day = 1565 W
Total energy required per day = 5855 Whr.

Total battery capacity (AH) $\frac{total\ backup\ energy\ required\ per\ day}{battery\ volt\ x\ depth\ of\ discharge\ x\ battery\ efficiency}$

$= \frac{5855}{12\ x\ 0.85\ x\ 0.85}$

$= \frac{5855}{8.67}$

□ 800 AH.

It must be noted that the following assumptions were made in the design.

1. A round trip efficiency of the battery which involved the energy retention ability of the battery after it has been charged was considered to be 0.85 (lead-acid battery)
2. Depth of discharge of battery 0.85.

Next is to determine the number of batteries to be used in the installation using the formular below.

Number of battery = $\frac{required\ battery\ capacity\ (AH)\ x\ \ Backup\ day}{required\ AH\ of\ battery}$

$= \frac{800\ x\ 1}{200\ AH}$ = 4 Batteries

Battery selection = 800 AH (200AH + 200AH + 200 AH +200AH)

In this design and because of my location (Southeast Nigeria) which is in the tropics, we have assumed that our days of autonomy [13], i.e., the number of days we could go without sunshine, either because the weather is cloudy or is raining. In this condition we chose 1.

Step 5 Setting up the Inverter

The solar panel produces direct current (DC) electricity. However, the appliances in our homes need alternating current (AC). Hence, the inverter converts the DC into the required AC. Inverters come in various power wattages and types, including square wave, modified sine wave and pure sine wave inverters [14]. Square wave inverters are not compatible for all devices, while the output of modified sine wave is not suitable for certain applications, like refrigerators. Pure sine wave inverters, which is the type used in this project is the best choice for solar systems.

To enable inverter power selection, the following calculations and assumptions were made.

Total power required per day = 1585

$$\text{Required inverter power} = \frac{total\ power\ required\ per\ day\ x\ safety\ of\ factor}{inverter\ efficiency\ (0.95)}$$

Safety of factor = 1.25 (according to NEC inverter should be 25% to 30% higher.

Required inverter power = $\frac{1585\ x\ 1.25}{0.95}$ = 2085.5 watts = 2.0855 kilowatts.

Required inverter power □ 2.5 kilowatts

Step 6 Connecting the Inverter and Battery

First, we started by wiring the controller with the solar panels. Secondly, we connected the pairing of the battery with the controller. Lastly, was to connect the controller to the DC load connector. For connecting the solar panel with the charge controller, an MC4 connect (separator) was used [15]. Once the controller is connected to the battery, its LED light begins to light up. Similarly, the inverter terminal was connected with the battery terminal. Load Guidance for Battery and Inverter [16]

Step 7 Charge Controller Selection

Calculations to determine the selection of the charge controller is done with these parameters

Battery bank voltage (v),
Total solar parcel power (w)

$$\text{Charge controller current } \frac{Total\ solar\ panel\ power\ (w)}{Battery\ bank\ voltage\ (v)}$$

$$= \frac{1400}{12} = 116.67 \text{ A}$$

Charge controller current = 120 A

Table 2.

	S/N	TV	Laptop	Decoder	Fan	Lamps	Blender	Fridge	AC
Battery: 200Ah 12V (Lead-acid)	1								
Inverter: 1.5Kva	1	1	2	1	1	14			
Battery: 200Ah 12V	2								
Inverter: 2.5Kva 24V Pure sine wave	1	2	2	2	2	14			
Battery: 200Ah 12V	2								
Inverter: 3.5Kva 24V Pure sine wave	1	2	2	2	2	14			
Battery: 200Ah 12V	4								
Inverter: 5Kva 48V Pure sine wave	1	3	>4	>4	4	20			
Battery: 200Ah 12V	8								
Inverter: 10Kva 48V Pure sine wave	1	8	>8	>8	8	>20	2	2	2

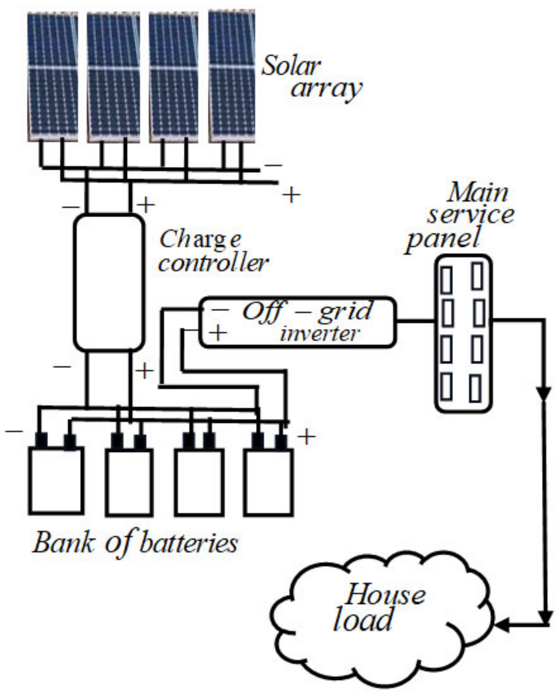

Figure Off -grid solar power system showing all the components

Conclusion

Sizing the solar power system simply means knowing how much power is needed to power the required appliances. For example, the size of the solar array depends on how much energy that is used on a daily basis. The size of battery bank depends on how many days that is earmark for energy storage to last, even through cloudy and rainy days. The charge controller needed to properly manage the energy between the solar panels and your battery must also be put into consideration. The size of the inverter needed depends on what appliances that would run on the system. The size of the wires and fuses also depend on how much energy that is going through the wires. To perform an accurate sizing of the household appliances given the amount of Kwh, i.e., the energy required by the appliances working for a given number of hours need also be considered. Also considered at the load-end are all the load-end losses arising from inefficiencies of the various components of the solar power system. The effect of the temperature on the battery to produce energy must also be put into consideration when designing for the solar powered system. As the temperature goes down, the lead-acid battery produces less energy. The discharge depth of the battery is also a factor. Correct sizing of the battery will extend the life of the battery, hence the entire installation. Luckily, in this part of the world, the tropics, the days of autonomy which means the number of days no power generation is possible as a result of rain, clouds etc., does not pose an issue. We are fortunate to have abundant sunshine regularly and that is a great advantage compared with people in the cold or temperate regions.

REFERENCES

1. Guda, H. A., and Aliyu U. O. (2015). Design of a Stand-Alone Photovoltaic System for a Residence in Bauchi. *IJET*, 5(1), 34 – 44, ISSN: 2049-3444
2. Ibrahim, U.H. Aremu, D.A. and Unwaha, J.I. (2013) Design of Stand-Alone Solar Photovoltaic System for Residential Buildings. *IJSTR*, 2(12), 187 - 194, ISSN 2277-8616
3. Lalwani, M., Kothari, D.P., Singh, M. (2011) Size Optimization of Stand-Alone Photovoltaic System under Local Weather Conditions in India. *International Journal of Applied Engineering Research, Dindigul,* 1(4), 951 – 961, ISSN - 0976-4259
4. Lesuanu, D. and D. Idoniboyeobu, (2018). Solar PV/Battery System Analysis for Faculty of Engineering Building, Rivers State University, Port Harcourt, Nigeria. 13
5. https://youtube.com/channel/uc5irLcuc.
6. Procedures for determining the performance of stand-alone photovoltaic system
7. https://www.nral.gov/docs/fy99osti/27.
8. 7.Okoye, C.O. and Solyalı, O. (2017). Optimal sizing of stand-alone photovoltaic systems in residential buildings. *Energ*y, 126: 573-584.
9. Ishaq, M., Ibrahim, U.H., Abubakar, H. (2013) Design of an Off Grid Photovoltaic System: A Case Study of Government Technical College, Wudil, Kano State. IJSTR, Vol 2 (12), pp 175 -181, ISSN 2277-8616175
10. Mandelli, S., Colombo, E., Merlo, M. and Brivio, C. (2014) A Methodology to Develop Design Support Tools for Stand-alone Photovoltaic Systems in Developing Countries. *Research Journal of Applied Sciences, Engineering and Technology* 8(6): 778-788, 2014 ISSN: 2040-7459; e-ISSN: 2040-7467
11. Ezenugu, I.A., Umoren, M.A. and Okpura, N.I. (2016). Performance Analysis of Stand-Alone Photovoltaic (SAPV) System for Category I Health Clinic in Orlu, Imo State, Nigeria. *Mathematical and Software Engineering*, 2(1), 35-47
12. Abhik, M.P., Subhra, D., and Raju N.B. (2015) Designing of a Standalone Photovoltaic System for a Residential Building in Gurgaon, India. *Sustainable Energy*, 2015, Vol. 3, No. 1, pp 14-24, DOI:10.12691/rse-3-1-3.
13. Saleh,U.A., Haruna, Y.S. and Onuigbo, F.I. (2015) Design and Procedure for Stand-Alone Photovoltaic Power System for Ozone Monitor Laboratory at Anyigba, North Central Nigeria. *IJESIT* 4(6), 41 – 52, ISSN: 2319-5967
14. Anyanime, T.U., Ubom, E.A. and Mbetobong, U.F. (2016). Design of Stand-Alone Floating PV System for Ibeno Health Centre Science PG, 4(6): 56-61
15. Ahmed, G. E. (2001), An optimal sizing of a photovoltaic powered rural zone family house ISES 2001 Solar World Congress, pp 1627 – 1634.

****