Improvement of Existing Solar Energy System in Mechanical/Mechatronic Engineering Department

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Abstract
Energy is among the basic inputs and fundamental driving forces for socio-economic and human progress and modernization. A sustainable energy supply can be achieved through the use of alternative energy sources; therefore, energy use is vital for maximum net-zero environmental footprint. This work looks into the opportunity of betterment in an energy system including an academic building block with five end-loading equipment. An energy evaluation is carried out on the end-use consuming equipment (i.e.; fans, lights, cooling system and ICT equipment and such other) in above mentioned five end-load sub-segments to determine main appliances for energy consumption, the overall energy consumption and potential saved/conserved energy. The analysis of energy consumption for each piece of equipment aids in identifying which equipment should be upgraded or replaced to conserve energy. Additionally, the feasibility of implementing rooftop solar power generation has been evaluated for integration into the overall energy load. Findings indicate that workshop equipment, lighting, and air conditioning play crucial roles in energy consumption within academic buildings. The feasibility analysis of onsite energy generation through a hybrid solar system revealed that the potential for energy savings is cost-effective. This implies significant energy-saving opportunities for the academic building.

Keywords: Solar-Energy; Generation; Improvement; Reducing economic impact and Sustainability

1.0 The challenge

The Mechanical Engineering department building at the Federal University Otuoke primarily depends on traditional grid-based electricity sources, which results in rising energy costs and a significant carbon footprint. The lack of an effective renewable energy solution not only affects the department's financial resources but also undermines the global pledge to promote sustainability and decrease greenhouse gas emissions.
Additionally, the absence of a self-cleaning mechanism for solar panels leads to decreased energy generation efficiency over time, requiring expensive manual cleaning efforts, [2, 10, 9]. To tackle these challenges, "The upgrade and implementation of a 3.5kVA solar power system with automated self-cleaning in the Mechanical Engineering department building," we will design and develop a 3.5kVA solar power system that includes an automated self-cleaning feature, [3, 4, 5]. This solution will allow the department to take advantage of clean and economical solar energy while sustaining the efficiency of the solar panels through automated cleaning, ultimately lowering electricity costs and fostering sustainability, [6, 7, 9].

2.0 Basics of Solar Power System (PV System)

A typical solar power supply system consists of solar panels (also known as photovoltaic or PV panels), a charge controller, and a power inverter equipped with a meter or monitoring system that tracks voltages, system conditions, and the electrical distribution network.
A solar panel is a device designed to capture sunlight and convert it into electrical energy, specifically in the form of direct current (DC).

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The photovoltaic panel is made up of silicon crystals, which react to sunlight and generate electricity through this process. These panels provide electricity for charging batteries and can power appliances directly or through an inverter. To generate more electricity, multiple modules are utilized, and any excess energy produced is stored in batteries for use during cloudy or rainy conditions.

There are various panel sizes, and they come in various voltage levels as well as ampere measurements. Their installation for systems upgrade can be either in series or parallel connections.

3.0 Factors affecting output from PV solar panels

i. Temperature

Output power of the module decreases with the module temperature. It gets a lot hotter a solar module on the roof so we would end with 50-75oc. Crystalline type modules normally have about 89% of the STC temperature derating factor as provided by IEC standard. thus a 3.5KVA module will run just about 85 watts (3.5KVA 0.89 = 3.115 KVA) on a cloudy spring/autumn day at max sunlight conditions.

ii. Standard test conditions

The solar modules generate direct current (DC) electricity. Manufacturers rate the DC output of these solar modules under standard test conditions (STC). These conditions can be easily replicated in a factory setting, allowing for consistent comparisons of products based on common outdoor operating parameters. The standard conditions include a solar cell temperature of 25°C and a solar irradiance (or intensity) of 1000 W/m², commonly known as peak sunlight intensity, which is comparable to the intensity observed during clear summer afternoons.

iii. Dirt and dust

Dirt and dust can build up on the surface of solar modules, obstructing sunlight and lowering their efficiency. However, normal dirt and dust tend to be washed away during the rainy season. The average annual dust reduction factor is 93% or 0.93.

4.0 System operation of the 3.5kVA solar power system

The solar panel captures energy from the sun and turns it into electricity. It does this by taking in sunlight through its modules, which creates free electrical charges in the conduction and valence bands. The electricity generated by the solar panel is then sent to the charge controller, as shown in fig 3.1. The charge controller manages how much electric current goes into and comes out of the battery. It stops charging when the battery is fully charged and starts again when the charge drops below a certain level. This ensures the battery is completely charged without getting overcharged. The regulated voltage from the charge controller is then sent to the solar battery. The batteries were a crucial part of this solar power system. They stored the energy for use later.

5.0 The solar power system improvement

i. Load Evaluation and Power Consumption

- A list of the electrical appliances that needed to be powered was made;
- The power usage in watts for each device was recorded;
- The number of hours each appliance was used every day was noted;
- The wattage of each appliance was multiplied by the daily usage hours to calculate the daily watt-hour consumption;
- The total weekly watt-hour usage was calculated by multiplying the daily watt-hour by the number of days per week the appliance would be used; and
- An automatic cleaning system for the PV panels was included.

ii. Solar components sizing

Getting the right size for each part of the solar electric system was important. This helps make sure the system generates the exact amount of electricity that is needed.

Common types of PV electrical systems for upgrading

There are two main kinds of electrical upgrades for solar power systems in homes.

One type connects to the utility power grid but doesn't have battery backup. The other type also connects to the grid but includes battery backup as well.

6.0 Determination of components specifications for the PV system

The number of panels multiplied by the maximum current and system loss is 1 x (2 x 19.4) x 1.3 = 50.44A.

A recommended 60A/24V solar charge controller is needed.

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The available power from the solar array is 1600 watts.
The system voltage is 24 volts. Using the formula P = VI, the current can be calculated as I = I = $\frac{P}{V}$ = $\frac{1600}{24}$ = 66.7A. Based on the IEEE standard table for current capacity for air, the cable size required is 16mm².

7.0 Inverter size determination

To calculate the inverter size, we first determine the total load. The inductive load (L):
L = (100 w x 4 = 400 watts)
The non-inductive load includes sockets and bulbs, totalling (130 watts x 5 + 20 watts x 4 =730 watts).
The capacitive load from the printer is 1000 watts.
Adding these together gives a total connected load of 2130 watts.
Then add 15% of this total, which is 319.5 watts, resulting in a total load of 2449.5 watts. Considering the inverter efficiency of 90% (or 0.9), the required inverter size is 2204.6 VA. Therefore, a 2500 VA (3.5 KVA/24V) inverter is recommended.
For the battery size, the day of autonomy is 1 day and the depth of discharge is 90% or 0.9.
Battery Size = $\frac{\text{ELD (Ah) x DoA}}{\text{DoD}}$ = $\frac{211.8\,Ah\times 1}{0.9}$= $\frac{211.8\,Ah}{0.9}$ =235.3Ah

The recommended capacity is a tubular battery of 240Ah/12V.
Number of batteries = $= \frac{235.3\text{Ah}}{240\text{Ah}}$ = 0.98

Approximately number of batteries proposed for use = 1.
Number of Battery in series = $\frac{\text{System Voltage}}{\text{Nominal Voltage of Selected Battery}}$ =24V/12V=2 in series
The solar charge controller
Number of the solar panel = 4 each 400watt
Therefore, 400W x 4 = 1.600watts

1600 Watts with a maximum current of (9.7x 2) =19.4A
Maximum voltage = 41volts ×2 = 82volts

8.0 Installation of the 3.5kv solar power system

- **Procurement of components for the installation of 3.5kVA solar system**

When getting all the materials for this project, choosing the right battery, inverter, solar panel, and charge controller was completely based on individual evaluations. The materials—solar panel, inverter, batteries, and charge controllers—were bought using the following price list: materials for installing a 3.5kVA solar system.

S/N	ITEMS	QUANTITY	UNIT PRICE (N)	TOTAL PRICE (N)
1	380 W solar panel	4	80,000	320,000
2	Felicity 12V MMPT charge control	1	35,000	35,000
3	Tubular Battery (220V)	2	180,000	360,000
4	2.5 KVA Inverter	1	320,000	320,000
5	Battery rack	1	10,000	10,000
6	6mm Wire	25 Y	800	20,000
7	Circuit breaker	1	10,000	10,000
8	Trunking	2	2,000	4,000
9	Fuse	1	3,500	3,500
10	Single Core AC	10 Y	800	8,000
11	Change over switch	1	10,000	10,000
12	DC wire (complete core)	30 Y	2,500	75,000
13	Workmanship			100,000
14	Miscellaneous			30,000

The materials listed above were all checked before being sent and were found to be in good condition. When all transportation costs were added, the total came to N293,100. This amount was collected through a group funding process. The next purchase was for upgrading the automated cleaning system used on the PV solar panel array. The procurement was made from the same supplier as the main parts used for installing the solar power system.

9.0 Test of the PV 3.5kVA solar system

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The solar panel was placed under the sun at a 45-degree angle facing southwest, where it received the highest sun exposure. Using a multimeter, a voltage of 40 volts was measured. While checking the voltage, the panel was slightly moved, and as it moved away from the sun, the voltage decreased. The output from the solar panel was connected to the charge controller with the correct polarity. When the voltage was checked again, it read 26 volts, which is suitable for charging a 24-volt battery made by connecting two 12-volt batteries in series. The charge controller had an indicator light that turned green when the battery was fully charged and a red light that came on when a load was connected to the system.

Each battery read 12.8 volts and then siamese i n series to give an output of 24 volts subsequently was affined to the inverter. The emf was 25.7 volts DC because the solar and t he charge comptroller were also engaged but without load then load was added to the inverter which gave an output of 220 volts and was left for about 30 proceedings after then it was seen again and the potential drop did not vary. The inverter had three indicators. The first displayed if the system was joined to the mains or not, the second displayed if the inverter system was switched *ON* or *OFF* and the third was to show if the system was experiencing any fault or not. The inverter also had an supplementary socket for plugging the inverter to mains to serves as different means to charge the batteries other than the solar system. When tested with the volt meter as it was plugged on the mains out, it read 14.4 volts which was essentially because of the batteries would commonly self-dispatch over time even when not in use. Since the inverter enclosed a triple cycle charger it could go forward to observe the bombardment with equalisation charge emf of about 12 volts just to make sure that the barrage fire does not firing even it was on secondary mode.

10. Battery Maintenance.

Regular test procedures to look for differences in colour, deposit in cell boxes and corroding on cells and connectors. All these parameters tell us the state of the battery.

Check electrolyte levels and refill using distilled water when needful.

Measure out and record cell emf with a DC voltmeter for discrepancies and fix them by checking the charging system and the battery contact points.

11. Power conditioning system-maintenance.

These systems have solid and complex designs and come with protective covering against power surges and system clog and so cannot fail easily. When essential, sustentation should be done by competent electrical technician.

12. Conclusions

The work is to sire 3.5kVA of energy to the departmental building, to serve as secondary energy source, induction was palmy and worked with efficiency as attached. nevertheless, during the promote of the system prerequisite, it was advised to adjust from 12 volts solar panel to 24 volts solar panel and from 12 volts bombardment and an another one more bombardment, which then became 24 volts system to fit the solar panel that was already purchased.

The solar system worked in effect when compared to diesel source, it was costly but for the first expenses. still, it was later seen to be cheap since the system needed no petrol to go but sunshine which was nature's free gift. thus, there was no need to time or limit the hour of power supply of the up and down experiences from the mains supply.

References

[1] Abu , N., & Rahman , A. (2014). Design and Construction of Square Sine Wave

[2] Ajiboye, J. A. (2016). Design and Implementation of a 5kVA Inverter,". Journal of Electrical and Electronics Engineering, vol. 9, no. 4, pp. 1-15, 2016. [Google Scholar] [Publisher Link], 1-15.

[3] Alok , D. (2015). Intelligent Cooling System for Three Level Inverter," 2015 Communication, Control and Intelligent Systems, 2015. [CrossRef] [Google Scholar] [Publisher Link].

[4] Badrul , H. (2022). Design, Construction and Installation of a 2KVA Inverter.". Kaduna: (An Unpublished Project Report) Submitted to the Department of Electrical and Electronics Engineering, Kaduna Polytechnic.

[5] 5Godwin , O. (2004). Design, Construction and Installation of a 100w Inverter.". Kaduna: (An Unpublished Project Report) Submitted to

DOI: https://doi.org/10.5281/zenodo.18073094

the Department of Electrical and Electronics Engineering, Kaduna Polytechnic.
[6]Olopade, M., & Sanusi, Y. (2009). Solar Radiation Characteristics and the Performance of Photovoltaic (PV) Modules in a Tropical Station. Journal of Science Research and Development, (2008 / 2009), 100-109.
[7] Osama, O., & Egon, O. (2007). An Online Control Strategy for DC Coupled Hybrid Power System.". IEEE Power Engineering Society General Meeting,.
[8] Bello Muhammad, Hamza Abdullahi, and Sani A. Muhammad, "A Design, Construction and Installation of 1000watt Inverter using Solar Power System,"2nd International Conference on Science, Technology and Management, pp. 2860-2865, 2015. [Google Scholar]
[9] O. O. Babarinde et al., "Design and Construction of 1kVA Inverter," International Journal of Emerging Engineering Research and Technology, vol. 2, no. 3, pp. 201-212, 2014. [Google Scholar] [Publisher Link]
[10] Alex Vlachokostas, and Nicholas Madamopoulos, "Quantification of Energy Savings from Dynamic Solar Radiation Regulation Strategies in Office Buildings," Energy and Building, vol. 122, pp. 140-149, 2016. [CrossRef] [Google Scholar] [Publisher Link] [Publisher Link]
[11] Tran , D. C. (2020). Research on Controlling DC/AC Converter Using Solar Power System for the Applications in Industrial,". SSRG International Journal of Electrical and Electronics Engineering, vol. 7, no. 12, 2020. [CrossRef] [Publisher, pp. 15-20,.

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