iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VI **Month of publication:** June 2017

DOI:

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Details of Photovoltaic Solar System Design Calculations and the Accessories

Engr. Dr. Okwu P I[1], Engr Okolo Chidiebere C[2], Engr Okeke Obinna3,Engr. Matthew D. O[4], Engr Ajuzie Uche[5]
[1,2,3,4,5]*Electronics Development Institute, Awka, Anambra State, Nigeria*

Abstract: A photovoltaic system, also solar pv power system, or pv system, is a power system designed to supply usable solar power by means of photovoltaics. The purpose of this article is to provide tools and guidelines for the installer to help ensure that residential photovoltaic power systems are properly specified and installed, resulting in a system that operates to its design specification. This article shows the important and principle criteria that describe a quality system, and key design and installation considerations that should be met to achieve the goal.
Keywords: Solar, photovoltaic, solar array, grid-connected, solar panel

I. INTRODUCTION

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture and artificial photosynthesis.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global.

PV (Photovoltaic) Power System

A photovoltaic system, also solar PV power system, or PV system, is a power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting cabling and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution otherwise called a charge controller.

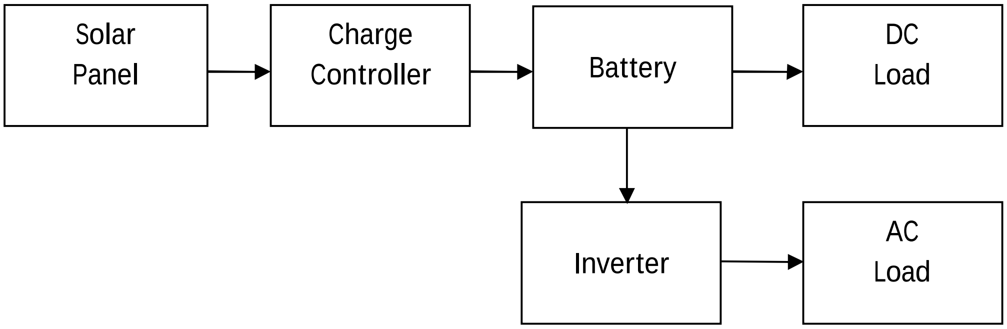
A. *Roof Mounted PV system*

Strictly speaking, a solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware. Moreover, PV systems convert light directly into electricity and shouldn't be confused with other technologies, such as concentrated solar power or solar thermal, used for heating and cooling.

PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts.

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Operating silently and without any moving parts or environmental emissions, PV systems have developed from being niche market applications into a mature technology used for mainstream electricity generation.



Block diagram for a solar system

B. Photovoltaics (pv)

1) *Photovoltaics (PV)* : covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry.A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. The first step is the photoelectric effect followed by an electrochemical process where crystallized atoms, ionized in a series, generate an electric current. PV Installations may be ground-mounted, rooftop mounted or wall mounted.
2) *THE SOLAR PANEL: The* solar panel is made up of several solar cells connected in series to give the required voltage. The solar cell is a combination of a p-type and n-type silicon semiconductor material separated by a pn junction
3) Types of Solar PanelThere are several types of solar panels with each having different efficiencies.The table below shows the various types with the corresponding efficiencies.

Types of solar panel	Efficiency
Monocrystalline	15-20 %
Polycrystalline	12-15%
Thin Film	6-8%

In a design requiring several interconnections of solar panels, only panels of the same type are used to ensure optimum performance.

4) *Efficiency of Solar Panel:* Although the sun radiates about $1000W/M^2$ of solar energy, it is only 20% of it that can be harnessed using solar panel. The efficiency of solar panel depends on the following factors:
a) Reflection***:*** The efficiency of solar panel depends on the amount of energy reflected by the panel. Most of this reflected energy is as a result of the silver contact used to complete the circuits of the solar cells.
b) Non-Usable Energy***:*** When the energy is too much such that the electrons jumping from the valence band to the conduction band jumps beyond the conduction band and as such energy is lost. It can also be that the energy is not enough to shoot the electrons to the conduction band thereby bouncing back and such energy is lost.
c) *Recombination***:** Energy is lost when an electron that has been excited to the conduction band recombines with a hole.
d) *Resistance***:** This is as result of the conductors such as the silver contacts used in making the panel.

In summary about 80% of the solar energy radiated by the sun are lost leaving only 20%.

5) *Solar Panel Calculation:* Here my interest is to get the number of solar panels that can source the current required to charging the battery.

$$I_{pv} = E_i / (V \times H)$$

Where

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

$I_{pv,}$ photovoltaic current = total current required to charge the battery from the solar panel
E_i= input energy to the inverter
V = system voltage = 12V
H = peak sunshine hour, the average number of hours the solar energy can be captured.
H = 5hrs.
Thus
I_{pv}= 4395.06/ (12 x 5)
= 73.25Amperes.
In order to compensate for the losses due to the inefficiency of the solar panel, 20% of $I_{pv}$is added so that:
I_{pv}= 73.25 + (0.2 x 73.25) = 87.9A.
With a solar panel of the above rating, the peak or open circuit voltage, V_P = 17.3V
Peak power, $p_p = I_{pv} \times V_p$
= 87.9A x 17.3V = 1520.67W
Number of solar panel = 1520.67/120 = 12.67
Thus the number of solar panel required is approximately 13 panels.

C. Insolation and energy

Solar insolation is made up of direct, diffuse, and reflected radiation. The absorption factor of a PV cell is defined as the fraction of incident solar irradiance that is absorbed by the cell. At high noon on a cloudless day at the equator, the power of the sun is about 1 kW/m²,on the Earth's surface, to a plane that is perpendicular to the sun's rays. As such, PV arrays can track the sun through each day to greatly enhance energy collection.
However, tracking devices add cost, and require maintenance, so it is more common for PV arrays to have fixed mounts that tilt the array and face solar noon (approximately due south in the Northern Hemisphere or due north in the Southern Hemisphere). The tilt angle, from horizontal, can be varied for season, but if fixed, should be set to give optimal array output during the peak electrical demand portion of a typical year for a stand-alone system. This optimal module tilt angle is not necessarily identical to the tilt angle for maximum annual array energy output

D. Grid-Connected Photovoltaic Power System

A grid-connected photovoltaic power system, or grid-connected PV power system is an electricity generating solar PV power system that is connected to the utility grid. A grid-connected PV system consists of solar panels, one or severalinverters, a power conditioning unit and grid connection equipment. They range from small residential and commercial rooftop systems to large utility-scale solar power stations. Unlike stand-alone power systems, a grid-connected system rarely includes an integrated battery solution, as they are still very expensive. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid.

E. Solar inverter

A solar inverter, or converter or PV inverter, converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical balance of system (BOS)–component in a photovoltaic system, allowing the use of ordinary AC-powered equipment

F. Inverter Rating Calculation

The inverter cannot be loaded more than 75% of its rating. In other words, it is recommended that the design is done in such a way that only 75% of the inverter rating is used.
Let I_R the inverter rating and using the CED which is the total load energy demand.
75% of I_R= CED
0.75 I_R = 3955.55

I_R =3955.55/0.75 = 5274.07VA

G. Solar charge controller

A charge controller may be used to power DC equipment with solar panels. The charge controller provides a regulated DC output and stores excess energy in a battery as well as monitoring the battery voltage to prevent under/over charging. More expensive units will also perform maximum power point tracking. An inverter can be connected to the output of a charge controller to drive AC loads.

H. Charge Controller Calculation

The charge controller is rated in Amperes. Its rating depends on the amount of photovoltaic current, $I_{pv.}$ To ensure that it is not overloaded, 20% of $I_{pv}$is usually added as an allowance.

Charge controller rating = I_{pv}+ (20% of Ipv)

= 87.9 + (0.2 x 87.9) = 105.48A

Thus two charge controllers of ratings 60A each will be suitable.

I. Battery

PV systems increasingly use rechargeable batteries to store a surplus to be later used at night. Batteries used for grid-storage also stabilize the electrical grid by leveling out peak loads, and play an important role in a smart grid, as they can charge during periods of low demand and feed their stored energy into the grid when demand is high.

Common battery technologies used in today's PV systems include the valve regulated lead-acid battery– a modified version of the conventional lead–acid battery, nickel–cadmium and lithium-ion batteries. Compared to the other types, lead-acid batteries have a shorter lifetime and lower energy density. However, due to their high reliability, low self discharge as well as low investment and maintenance costs, they are currently the predominant technology used in small-scale, residential PV systems, as lithium-ion batteries are still being developed and about 3.5 times as expensive as lead-acid batteries. Furthermore, as storage devices for PV systems are stationary, the lower energy and power density and therefore higher weight of lead-acid batteries are not as critical.

PV systems with an integrated battery solution also need a charge controller, as the varying voltage and current from the solar array requires constant adjustment to prevent damage from overcharging. Basic charge controllers may simply turn the PV panels on and off, or may meter out pulses of energy as needed, a strategy called PWM or pulse-width modulation. More advanced charge controllers will incorporate MPPT logic into their battery charging algorithms. Charge controllers may also divert energy to some purpose other than battery charging. Rather than simply shut off the free PV energy when not needed, a user may choose to heat air or water once the battery is full.

Following are terms associated with batteries:

1) *State of Charge*: This is the level at which the battery is charged at a particular point in time. It starts from 0-100 percent.
2) *Autonomous Day*: This is the number of days the battery can be used without charging.
3) *Depth of Discharge (DOD)*: This is the percentage of the battery charge that has been discharged or can be discharged. It can be fixed for a given battery. The higher the DOD the higher the longevity of the battery. For example, the table below shows the life span of a battery depending on the DOD.

Depth of Discharge (DOD)	Battery Life Span
80%	6 months
50%	3 years
20%	15 years

Battery DODs and their corresponding life spans.

J. Battery connections

Only batteries of the same capacities can be connected together to ensure optimum performance. Following are various ways batteries can be connected:

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

1) *Series Connection*: When batteries are connected in series, the net voltage is sum of the individual voltage of the batteries while the current remain the same.
2) *Parallel Connection*: When batteries are connected in parallel, the net current is the sum of the individual currents of the batteries. The net voltage is the same if all the batteries are of the same capacity otherwise the net voltage is the voltage of the battery with the lowest performance.
3) *Series-Parallel Connection*: This is the combination of the series and parallel connections to achieve a required system voltage and current.

L. Solar system design

This show how the ratings of each of the components shown in the block diagram above are gotten by design calculations.

M. Consumer energy demand (ced).

This refers to the sum total of the energy demand by the loads to be powered by a solar system. Before one goes into designing a solar system, it is needful that one understands the power demand of the individual loads and the duration of usage of each load to facilitate the design.

Mathematically, the CED for a given load is expressed as:

CED = Q x P x T

Where

Q = Quantity of the load.

P = power rating of the load in Volt-Ampere (VA).

T = Duration of usage of the load per day in Hour (H).

The unit of CED is Volt Ampere Hour (VAH).

The table below shows the CED calculation for the given loads:

Load	Quantity	Power Rating (VA)	Usage Duration (Hour)	CED (VAH)
Ceiling fan	1	66.67	12	800.04
Lighting bulb	3	22.22	8	533.28
DVD player	1	111.11	3	333.33
Television	1	66.67	3	400.02
Electric Iron	1	1111.11	1	1111.11
Laptop	2	72.22	4	577.76
Decoder	1	66.67	3	200.01

Total CED = 3955.55

N. Battery Capacity Calculation

From the table above, the total CED is the minimum energy demand from the inverter. The input energy to the inverter in order to get the expected output is given below.

Efficiency, η = Energy output (E_o) / Energy input (E_i)

Using $\eta = 0.9$

E_i = 3955.55/0.9

= 4395.06

Thus the input energy to the inverter = 4395.06VAH.

Now, to get the capacity of the battery that will produce this energy using 12V battery or system voltage of 12V and DOD of 50%:
Battery Capacity, C = 4395.06/ (0.5x12)

= 732.50Ah

The required battery capacity is approximately 750Ah. With these result three batteries of capacities 250Ah can be connected in parallel to give 750Ah.

O. Standby Mode Power Consumption

The standby mode consumption is the power the system consumes when it is not delivering power to the load or when it is in sleep mode. The value of the standby mode power consumption is 5VA per hour. Assuming the system runs for 24hrs then the value will be 120VA and this is added to the inverter rating.
Thus the rating of the inverter is (5274.07 + 120) VA.
Therefore the rating of the inverter that will be suitable for this design is 5.5KVA.

P. Cable size calculation

In several occasions the solar panels may be mounted at some distance away from the battery in a bid to track maximum energy hence a distance of separation.
In order to reduce amount of voltage drop along the cable from the solar panel, the distance of separation between the panel and the battery is limited to ten meters (10m).
The cross-sectional area of the cable is calculated as follows:

$$A = (2D \times I_{pv}) / (\sigma \times \Delta v)$$

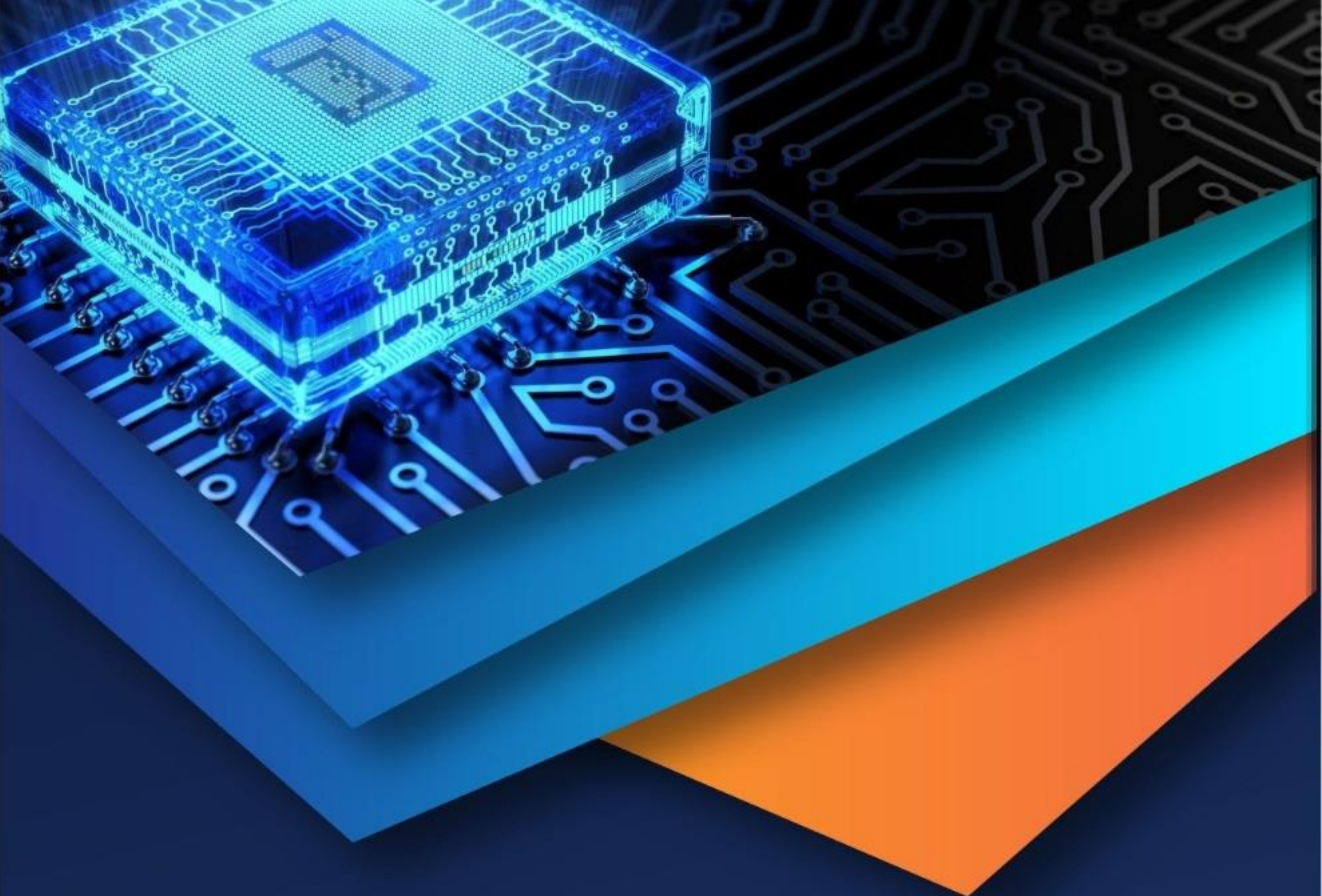
Where
A = cross-sectional area of the cable
D = 10m = maximum length of the cable
I_{pv}= current from the solar panel
σ = conductivity of the conductor used for the cable
Δv = total voltage drop by the cable. This is usually taken to be 3% of the system voltage.
As calculated before;
I_{pv} = 87.9A
σ = 56000000A/V
Δv = (3% of 12V) = 0.03x12 = 0.36V
Therefore;
A = (2x10x87.9) / (0.36x56)
= 87.2mm^2

II. CONCLUSION

Once a system design has been chosen, attention to installation details is very critical. Recent studies have4 have found out that 10-20% of new PV installations have serious installation problems that will result in significantly decreased performance. In many of these cases, the performance shortfalls could have been eliminated with proper attention to the details of the installation.

REFERENCES

[1] Guda, H. A and Aliyu U. O, " Design of standalone Photovoltaic system for a residence in Bauchi" International journal of Engineering and Technology Volume 5 No 1, Jan 2015
[2] Solar Energy International, Carbondale Co www.solarenery.org.
[3] Photovoltaic: Design and Installation manual, Solar Energy international (SEI), 2007
[4] Chetan Singh Solanki, " Solar photovoltaic: Fundamentals and application PHI learning Pvt 2011.
[5] Okafor C. "Designing of photovoltaic systems for a residential building " Project report
[6] Bhandari, R. and I. Stadler (2011) "Electrification using Solar Photovoltaic Systems " Applied Energy Vol 88, 458 - 465.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY