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# Design and Performance Analysis of Stand Alone Solar Photovotaic System of Distributed Generation

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**ABSTRACT**
Solar photovoltaic (SPV) systems convert sunlight directly into electricity. A small power system enables homeowners to generate some or all of their daily electrical energy demand on their own roof top, exchanging daytime excess power for its energy needs in nights using SPV distribution generation, if it is supported by the battery back-up. A SPV power system can be used to generate electric energy as a way of distributed generation (DG) for rural areas.

Several approaches have been proposed to improve efficiency of SPV system and to provide the proper ac voltage required by residential customers. For this purpose, dc-dc converters have been explored extensively to meet the required electric energy demands by these systems using a battery back-up.

A converter is designed to charge the battery. The battery voltage is converted into ac supply using an inverter. The design of a solar power system is a process which involves many variables that have to be adjusted in order to obtain optimized parameters for system components.

In this work the design and performance analysis of different blocks that constitute the PV array, a controller for maximum power point tracking (MPPT), a dc-dc converter, a battery block, an inverter (with filter) and the feedback control loop with controller will performed.

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## I. INTRODUCTION

The sun provides the energy to sustain life in our solar system; solar photovoltaic (SPV) systems convert sunlight directly into electricity. In Stand-alone (SPV) systems special attention must be paid to the load. In fact the bulk of the problems encountered with system operation can be traced back to inefficient appliances and processes or unmatched loads,

The exploitation of solar energy for electricity production in the last few years has been increasing substantially as compared to other renewable resources, majorly because of the photovoltaic (PV) technology as it is the best and reliable way of converting solar radiation into electric power.

Due to the modular nature in comparison to other renewable technologies, the solar PV technology emerges as an ideal solution for off grid power.

This technology has gained a great attention for his successful attempts to supply electrical power to autonomous off-grid rural areas and since many implementations has been successfully done worldwide. Moreover; owing to zero sound pollution and green house gas emission, it highly contributes towards the sustainability of the environment.

In addition, its production capability can be conveniently expanded as per need and low maintenance is required due to the absence of any moving parts.

`Depending upon the consumer demands, a variety of configurations, ranges from few watts to hundreds and from hundreds to kilo-watts power systems and micro-grids can be designed using this technology for small housing and business communities either in urban or in remote localities .

But, the major problem with this technology is its high initial cost. However, A dramatic reductions in prices of PV panels or modules have been observed worldwide in the last few years due to the growth in their demands and competitiveness of the markets.

## II. SURVEY

This definitive guide to solar site survey will provide you with all the necessary practical info.

Here you will find described some commonly valid principles that will help you ensure

the optimal performance of your solar panel system thus maximizing the amount of solar-generated electricity. The below-provided guidelines apply both to residential (home, office) and mobile solar panel systems (motor home, caravan, camper, RV). Also, you should mind that it is in your interest to be equipped with some essential knowledge about how to survey your site and also about orientation, tilt angle and optimal mounting of the solar array. If you decide to have your site surveyed, be sure that the solar vendor you select relies on your unawareness of such info and most probably will use certain non-effective shortcuts just to perform the solar system installation in due time thus neglecting some important energy efficiency issues.
Is your building solar-ready?

Even if your area and location have a good solar potential, your building might not be suitable for installation of a photovoltaic system.
Your building is prepared for installing a solar system if:
You have already made it energy-efficient.
The roof of your building (or your yard) is unshaded, at least during the sunny hours (normally six) of the day.
Its roof has a Southern (or Northern, if you live in the Southern hemisphere) orientation.
The roof is in a good condition.
How to assess your location for the solar resource?

The spot where you intend to install photovoltaic solar array should have:
a) A clear and unobstructed access to the sun throughout the day (between 9 a.m. and 3 p.m.) and throughout the year.

This means lack of any obstacles between the sun's rays and the solar arrays surface – trees, chimneys, lamp-posts, neighbor buildings, etc.

It should be noted that a spot may be unshaded during one part of the day and shaded during another part of the day.

Furthermore, a site unshaded in summer might be shaded in winter, as the low position of the sun in winter casts longer shadows.

b) Preferably a South-facing (or North-facing, if you live in the Southern hemisphere) roof.

True South (or True North, if you live in the Southern hemisphere) orientation is not mandatory.

A somehow Southeast or Southwest (for the Southern hemisphere Northeast or Northwest, respectively) facing roof is also acceptable.

It has been proven that deviation within 20-30 degrees of the True South (or True North, if you live in the Southern hemisphere) results in less than 10% degradation of PV array's performance, which is fairly acceptable.

Pure Eastern or pure Western orientation not recommended, since as a rule, solar photovoltaic panels should be exposed to direct sunlight for at least 6 hours a day.

You should mind that installing a solar PV system on a roof facing East or West might result in 20% degradation of system performance, which is a serious compromise!

The roof can be either sloped or flat. Flat roofs allow easier to implement the desired tilt angle of the PV array, but a sloped roof will do as well.

c) Enough space for placing solar panels
The area you need for your PV system depends mainly on:

How much energy it is designed to produce
Types of PV panels you are going to install (monocrystalline, polycrystalline or thin-film)

The size of the PV panels (to a lesser extent since, as a rule, PV panels do not vary much in size).
The less efficient photovoltaic panels you use, the greater the area you need for your solar array but also the lower the costs.

Monocrystalline panels are the most efficient solar panel type while thin-film panels are the least efficient ones.

Why does the condition of your roof matter?

A PV system can be installed on any roof type.

Regarding roof mounting, there are two options for installing PV panels – either mounting the solar panels on the roof or replacing the roof tiles with PV panels.

As a rule, roofs with composition shingles are the easiest to work with, while those with slate are the most difficult ones.

Here are the drawbacks in case of photovoltaic panels mounted on the roof:

Panels must be removed upon performing any roof repair or replacement activity.

Installation of brackets and racks could cause roof leaks.
Roof warranty may be affected.

Some people might find this unattractive.

However, roof-integrated installation costs amount up to 40% more compared to roof-mounted installation.

If your roof is relatively old and is to be replaced in the near future, in order to minimize any redundant costs, a smart idea would be to replace it at the time the solar power system is being installed.

If you have a new roof, you should consult both your PV provider and roof repair company how the installation of a solar power system will affect your roof warranty.

Certainly, solar panels can be placed on the ground as well, on a fixed or tracking mount.

Performing a site survey is the starting point for launching every photovoltaic system.

When searching for a proper site to install the solar array, you should consider:

The orientation towards the sun Lack of any shading obstacles (during the whole day and throughout the whole year!)

Minimization of the length of the DC cables between the PV array and the inverter
Aesthetics
Protection from theft and vandalism Easy access for installation and maintenance of the PV array.

## III. Methodology

Following steps are taken for the IRES based power generation for the electrification of remote site villages,

**1) Demand Assessment:** Find the load demand using accurate load forecasting of remote villages. Load assessment can be done by taking the interview of local bodies, school teachers etc. The following factors may be considered during the electrical load survey:

- Demand for street lighting,
- Number of schools, health centers, commercial establishment, and their energy demand,
- Number of villages, houses,
- Population
- Number of small industries with energy requirement,
- Miscellaneous demand.

**2) Resource Assessment:** Calculate potential available in solar, wind, MHP, Biomass and other renewable energy resources using meteorological data available.

**3) Constraints/barriers:**

- Annual electricity demand,
- Potential,
- Reliability,
- Emission,
- Employment.

**4) After doing this, one approach is adopted out of following two approaches:**

a) Approach I (Integrated Approach): In the first approach, demand is fulfilled by one or combination of more than one renewable energy resources.

- Stand alone SPV with battery storage,
- Stand alone Wind with battery storage,
- SPV-Wind with battery storage,
- SPV-Wind-MHP with battery storage,
- SPV-Wind-MHP-Biomass with battery storage,

b) Approach II (Hybrid Approach):
In this approach, Demand is fulfilled by hybrid approach. Demand can be met by combination of renewable energy resources with conventional sources (diesel generator set, thermal plant).

- PV/wind/diesel generator HRES,
- PV/wind/fuel cell HRES,
- Biomass/wind/fuel cell HRES

5) Optimize the selected system configuration with suitable technique.

## IV. PROBLEM/SOLUTION

When an off-grid system goes down, it is often challenging to know what to do next. Our technical team has put together a list to help you diagnose the problem so you can get your system back up and running. Understanding what is wrong will help you save time and money, no matter what the problem is. The key is to look at all aspects of your system and avoid assuming anything when troubleshooting. These valuable tips and common problems will jump start your solution.

**1. Check all wires, connections and fuses.** Tighten screw terminals. They can loosen over time due to corrosion, freezing and thawing cycles, or from vibration in transportation or RV applications.

Check for reverse polarity connections. There are sometimes no warning indicators.

Check terminal and wire labels or use a voltmeter.

Replace blown fuses, corroded wires or terminals, and any wires exposed from insulation abrasion.

**2. Check indicator LEDs or LCD icons on your charge controller.**
Most charge controllers have helpful indicators to diagnose problems. Check the product manual if you need help identifying what a message means. This could quickly get you to a solution. Low Voltage Disconnect (LVD) is a common error when an off-grid solar system is down. Check the battery voltage to verify, or when available, check a controller data logger for the telltale sign of greater energy used by loads than energy going to charging batteries. Potential causes include: Lack of sun to recharge the batteries. Battery capacity reduced in cold weather. Load working longer than designed. More load added than original design specifications.

**3. Check the solar panel's access to the sun and if the solar panel is performing properly.**
Pay attention to parameters that can impact performance and energy production:

Clean panels. Dirty panels can lead to significant loss of energy production.

Check for burned out solar cells.

Check junction boxes for damage such as loose wires, corrosion, or blown diodes.

Remove shade. If 10% of a solar panel is shaded that does not mean you should expect 10% less output. Cell stringing will cause a much higher percentage of lost production.

Use a digital multi-meter to check the open circuit voltage of each individual solar panel and compare the data with the manufacturer's datasheet for your PV module to help confirm performance is as designed.

**4. Check battery performance.**
Take your batteries to a professional to have them tested.
Compare battery operating specifications to weather data to determine if extreme weather is impacting performance.

Battery specifications can be found on the product datasheet or manufacturer's website.

**5. Re-check design parameters.**
Extreme weather conditions can exceed original design parameters and cause poor system performance.

Check worst-case sun hours for your region and compare to design parameters.

Check battery capacity days with no sun and compare to design parameters.

Review calculations with today's load usage and weather conditions. The original design may not account for extreme weather conditions or added load.

Confirm tilt angle is ideal all year with consideration to azimuth.

Re-evaluate losses throughout a system:

Voltage drops and power losses can be minimized with larger wires.

If there is an inverter in the system, confirm its energy consumption was factored into calculations.

**6. Check appropriate ventilation to prevent overheating.**

Electrical equipment can overheat and temporarily shut down. Inverter(s) might shut down without adequate ventilation. Controllers might limit charge current more than expected due to heat. To address overheating:

Check product manuals for guidelines on correct mounting style, spacing and ventilation.

Clean system equipment and vents to remove dirt and debris that interferes with ventilation.
Assess if space and ventilation in enclosures are appropriate.
Keep equipment out of direct sunlight for best performance.

## V. CIRCUIT DIAGRAM

Due to advancement in manufacturing process the cost of solar PV modules is showing a descending trend. A module is made up of several tiny cells and an array is created by grouping of modules

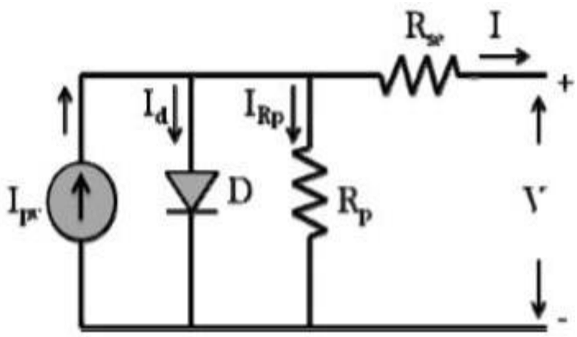


**Fig.1** Equivalent circuit of a solar PV cell

## VI. FLOWCHART

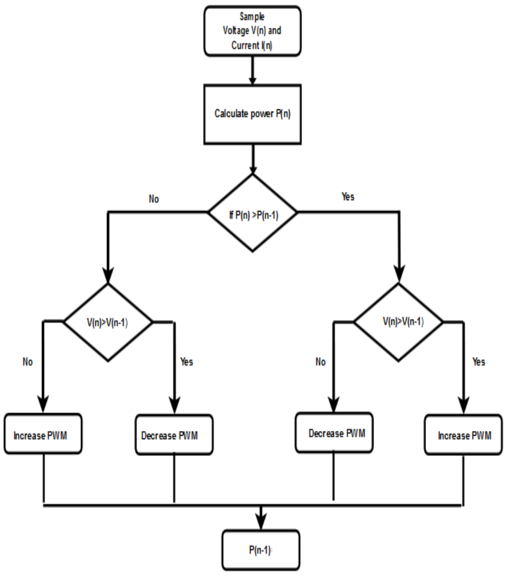


**Fig.2** Flowchart of MPPT P&O,

Maximum Power Point tracker is used to extract maximum possible power from the solar PV modules. MPPT tracks the variations in the power output and sets the module operating point to deliver the maximum possible power output. In this analysis a Perturb and Observe algorithm based MPPT is modeled. But one disadvantage of this method is under rapidly varying conditions the performance is poor. Fig.1a describes the P&O algorithm.

**Block diagrams related to work**

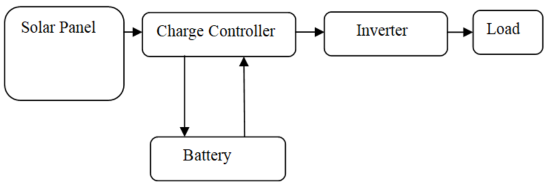


**Fig. 3** Stand alone solar PV system

## VII. OBSERVATION

There are not many studies to assess the environmental feasibility of SA systems which reinforces the notion that utility of Standalone systems is more of accessibility driven than due to environmental considerations. Financial feasibility analysis is performed from the market and entrepreneurial interests to explore the financial incentives, and other subsidies that make the business attractive. But there is no way one can afford to ignore assessment of the systems for their techno-economic-environmental feasibility as these parameters are location specific and the successful operation of the systems entirely depend on these parameters at a given region. It is also observable that systems which are uneconomical for a given load factor may become feasible for higher load factors. This opens up the discussion on what should be the ideal size, capacity factor and load factor range for which the system becomes feasible. Some of these questions were answered in the literature using optimization models. But it acts as a background for the design of the systems, which will be discussed in the next section.

## VIII. DISCUSSION

A free standing or Stand Alone PV System is made up of a number of individual photovoltaic modules (or panels) usually of 12 volts with power outputs of between 50 and 100+ watts each. These PV modules are then combined into a single array to give the desired power output. A simple stand alone PV system is an automatic solar system that produces electrical power to charge banks of batteries during the day for use at night when the suns energy is unavailable. A stand alone small scale PV system employs rechargeable batteries to store the electrical energy supplied by a PV panels or array.

Stand alone PV systems are ideal for remote rural areas and applications where other power sources are either impractical or are unavailable to provide power for lighting, appliances and other uses. In these cases, it is more cost effective to install a single stand alone PV system than pay the costs of having the local electricity company extend their power lines and cables directly to the home.

A stand alone photovoltaic (PV) system is an electrical system consisting of and array of one or more PV modules, conductors, electrical components, and one or more loads. But a small-scale PV system does not have to be attached to a roof top or building structures for domestic applications, they can be used for camper vans, RV’s, boats, tents, camping and any other remote location. Many companies now offer portable solar kits that allow you to provide your own reliable and free solar electricity anywhere you go even in hard to reach locations.

## IX. CONCLUSION

The design and performance study of a standalone solar PV energy system have been carried out using a fly back converter, battery and a single phase voltage source inverter. The battery charging has been achieved through maximum power point tracking which gives sufficient backup for 16 hours. The controller performance under various load conditions has been investigated and it has given required response under nonlinear load conditions. The results obtained for harmonic distortion of this system for both linear and nonlinear loads are within the 5% range specified by IEEE-519 standard. Performance of the system for the load variation is improved due to feedback PI control applied to VSI, so depending on the requirement one can choose it for low power application.

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