A Plan to Study the Effect of Solar Panel Inverter Overrating and Application of Correctly Rated Inverters to Increase Solar Panel Efficiency

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Abstract

Our proposal would directly impact the goals set out by the Solar Energy and Technology Office by helping to increase solar panel energy yield and therefore make it a more viable option to replace non-renewable resources. Once the energy yield of the panels increases, the cost for solar energy will decrease significantly; a lower cost for solar energy will allow more of the nation's infrastructure to adapt to the technology. [1] To increase solar panel efficiency, we will analyze the research being done at Michigan Tech and its Solar Energy Research Center to further the research of inverter overrate and its effect on solar panel efficiency paired with solar panels and solar concentrators to further increase energy yield.

Introduction

Use of renewable energy is a concern for the United States due to climate change and scarcity of nonrenewable resources. Dependence on nonrenewable energy sources such as fossil fuels is unsustainable, leading to opportunities in the advancement of energy technology. The current average cost to install a solar panel system to power the average house is around $30,000.[6] Through this research we are hoping to decrease this cost to make solar energy more accessible for homeowners and increase the amount of solar farms in the US. The cost of solar energy production has to be drastically reduced to make solar energy a viable alternative energy solution. The current means of cost effective solar energy production requires an extensive array of panels and equally large equipment to store the charges.[6] In order to increase the solar energy production of the nation and reduce the cost of solar energy production, new technologies and/or methods for the production of solar energy have to be implemented. Solar panels require a larger surface area to produce sufficient power for a house or building.[6] The large area of solar panels for needed power yield is a constraint for solar energy production. Using smaller solar panels with higher concentrations of sunlight with solar concentrators (curved mirrors) can help to make it possible for future models to be smaller and less expensive overall.

Background

Why Solar Energy:

Solar energy will have a major role in the renewable energy market and current technology can be improved upon in several ways.[1] Power processing systems (P3S's) transform solar energy into electricity, however, the current systems can be improved upon to lead to increased efficiency.

Solar panels are a quickly expanding resource in the renewable energy market.[2] The most common setup for solar photovoltaic (PV) systems is in a parallel row fashion. PV P3S's comprise each individual panel unit.[1] The main focus of this previous research was the lack of inverter reliability or durability which resulted in the trend of using overrated inverters, which decreases energy yield. This is especially true in climates that are not inherently ideal for solar due to weather or other climate factors.[1] This has slowed the acceptance of solar power in the U.S. as a sustainable source of electricity.

Solar Panel Theory:

Solar panels and inverters are the main components in P3S systems. Panels are usually comprised of two layers of silicon; a commonly used semiconductor. A PV cell uses photons found in sunlight, to knock electrons off a semiconductor which travel from negative to positive layers and creates a voltage differential. A load is then applied to the two layers and electricity flows through the circuit. The current created in solar panels is direct current (DC), however for this electricity to be used in homes it needs to be converted to alternating current (AC).[5] String inverters are the most common type of inverter used, with 50% of panels employing the technique of grouping panels into parallel 'strings' that are connected to a single inverter.[2] Inverters are replaced between three and five times over a typical 20-year lifetime of a PV system.

Inverter failure is caused by stress and overheating. Longer lasting inverters will increase reliability of overrated inverters, or inverters whose power rating is rated for the highest possible power creation level. However due to seasons, weather, etc, peak power generation is rare throughout the year. An underrated inverter will run at higher efficiency for most of the year, while an overrated system is only efficient for a small fraction of the year, because there are other components working with the underrated inverter, such as fans and advanced bonding materials used to prevent overheating.[3]

Current Knowledge:
The use of planar reflectors in conjunction with PV cells proves to be an effective way to increase the power ratio of those cells. Testing at the OSOFT facility in Kingston, Ontario concluded that a set of PV cells and a planar reflector can increase the power ratio upwards of 45 percent of the optimal power ratio. This cell setup could be added retroactively to solar farms to increase the efficiency any solar cell.[1] The power inverters used in solar cells tend to be unreliable in certain situations, specifically with their thermal management and heat extraction methods.[2]

Research Question:
Research done to replace over standard overrated inverters is applicable to implementation of panels in new systems and can be applied to P3S systems already functioning. This is to say that current solar power technology is using overrated inverters to avoid inverter failure due to overheating or overcharging. Inverter failure causes solar panels to stop creating electricity, and time needed for repairs or inverter replacement decreases a panels net power yield. Due to the effect of overrate on efficiency of solar panel arrangement, particularly for panels with concentrators it is a necessary step to increase the power yield of solar panels.[3]

Remaining Questions:
Some things to consider, if this project is to move forward would be the estimated cost of upgrading the old technology with the new. If a better version of the solar panel is developed through this research how much will it cost to replace the standing technology with the new technology?

Also, will the new technology be dispersed through government incentives - similar to the old technology - or privately? Lastly, how will this research obtain the “middle ground” between high and low rated P3S’s? In order to make them as efficient as possible this is the overall goal of this proposal, but what methods will be used to obtain this goal?

Previous Research
Dr. Pearce from Michigan Technological University, in partnership with Queen's University have researched non-tracking planar concentrators (NTPC). NTPC are curved mirrors used to concentrate sunlight on solar panels; some designs require both the solar cell and concentrators to follow the path of the sun to maximize their output. Dr. Pearce, however, focused on using the planar concentrator in place of motion tracking. After implementing NTPC they were able to increase the efficiency of traditional low concentration PV systems by 40%. This allows a retroactive installation of NTPC for solar cells to increase the efficiency.[1]

Outdoor Testing:
Testing was performed at the Open Solar Outdoors Test Field (OSOFT) in Kingston, Ontario

with a set of PV sensors was set up next to a wide planar reflector, which would concentrate more sunlight onto the panels. The testing procedure involved varying tilt angles 15°, 20°, and 57° for the planar reflector. The setup of the planar reflector would allow the solar panels to produce more electricity at a drastically reduced cost. Instead of having to purchase more efficient solar panels or buying a larger quantity, a large scale reflector could be placed in a spot where it can effectively increase the power yield of the panel. Two different reflecting materials were used on the planar reflectors: foylon, and Mylar. After two years, both materials exhibited a degradation in their reflectively upwards of 19%.[1]

Solar Simulator Testing:
Small scale testing of the reflector system was constructed to demonstrate that the experiment, performed under laboratory conditions, would validate large scale data. Voltage was measured across a range of 0-90°. Obvious trends formed in the data, such as a spike in voltage once the reflected light hit the bottom of the sensor. Also, a gradual decline formed in the data sets as the reflector image extended beyond the top of the sensor.[1]
Experimental Results:
The implementation of a non-tracking planar system demonstrated a significant increase in the power ratio (45-40%) for the flat glass and prismatic PV cells; however, the PV cells were angled at 57 °, which is a 22 ° difference from the optimal angle for that location. A secondary reflector setup was positioned with 5° of the optimal angle and only recorded an 18% increase in the power ratio for both glass surfaces.[1]

Need for Further Research:
An overrate is where a system is matched with a lower power rated inverter which is used so peak efficiency of the inverter is reached longer. However, throughout the year peak efficiency where solar radiation is at its max is seldom reached due to weather, seasons, etc., so an overrated inverter often underperforms. Further research of effects of direct current (DC), current that flows one way, overrate is needed because by using concentrators any loss in energy production due to inverter settings will be drastically larger than the amount of energy lost by standard panels. Researching the effects of DC overrate could further increase the efficiency increase when implementing NTPC to traditional PV systems.[1]

Methods
Type of Methods Proposed:
For this proposal, we plan to complete our research by using both quantitative and qualitative methods. The quantitative methods that will be applied to this research are the implementation of three different locations, with varying levels of solar radiation, of solar farms. There will be a location with high, low, and medium solar radiation, so that the data can be compared and contrasted, to help determine the best rated inverter for each location.

Each location will also be tested using two differently rated inverters, depending on the location, they will either be underrated or overrated inverters. This is to help determine the most effective inverter, that will keep the solar panels on and collecting energy without overheating. It is also possible that some sort of cooling device will be used in an attempt to keep the solar panels from shutting down when they are trying to save the hardware from overheating.

The qualitative methods that will be used are gathering maintenance records regarding the solar panels. These records will help determine how often solar panels shut down due to overheating, or other causes, which will help to quantify the overheating problem and rate its importance. If solar panels are shutting down to keep from overheating, this is necessary to protect hardware, but will decrease a panels net power yield.

Different Stages Involved:

There are three proposed phases for full experimentation with different combinations of power inverters. The first proposed phases involve the research of the various power inverters that will be tested and research of testing locations. The continental United States roughly lies within a latitude of 25° to 49° north of the Equator. Researchers will determine three areas of interest within the contiguous states that exhibit low, medium, and high solar radiation values. Solar radiation data will be collected from other academic studies and new data will be recorded in proposed locations as well. A solar array control group, featuring the standard 5 MW power inverter, will be installed congruently with each experimental solar array. The experimental solar arrays will be comprised of similar panels connected to power inverters with ratings ranging from 4.1-4.7 MW.

The second phase of the proposed research, experimentation, involves the implementation of the various power inverters within solar arrays across the all three test locations. The cells will go undergo energy generation for a standard solar year (365 days, 5 hours, 48 minutes, and 46 seconds). During this period, all power generation, solar data, and maintenance records will be stored and prepared for analysis.

The final phase incorporates the analysis of power generation data and maintenance records. Once the solar year has been spent collecting data, overall trends will begin to emerge from the data sets. Each testing location will provide their analysis for the best solar array group. Further testing may be required if multiple designs provide similar benefits. The trends in solar array groups can then be applied in small across regions with like solar radiation values, and further experimentation and analysis will be performed.

Efficiency of Methods

These methods are cost effective because we will focus on working with solar farms already in use so that we can use yearly solar radiation values already recorded to choose the inverter ratings. By adding new strings of panels and replacing individual components at the same farm we can directly compare the efficiency changes for replacing inverters on old solar panels and creating new solar farms to see if increasing efficiency by using regular or underrated inverters is a plausible application for designing new solar farms, for improving the efficiency of old farms, or both.

This research will be able to be applied to increase power yield of standard panel inverter combinations and it then can be used to predict how overrating will affect panels paired with mirrors to amplify solar radiation

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Appendix

Investigators

Brooke Powell, Scientific and Technical Communication (B.S), writing of all sorts, technical documents, strong editing background, and introductory experience/classes in engineering and physics labs.

Taylor Kaminski, Applied Physics with a concentration in solar energy. Part of Aerospace Enterprise on the Power team that deals with solar panels that supply the satellite power. Experience in writing research proposals, reading and analyzing papers.

Jacob Laidlaw, Mechanical Engineering (B.S.); mechanical aptitude, drafting scientific reports for multi-disciplinary teams (co-op and Aerospace Enterprise), creative brainstorming for complex problems.

Proposal Comments

1. What do you consider to be the successes of your proposal?

One success of our proposal is that it has a narrow focus, on increasing solar panel power yield. We identify work that has been done to increase solar panel power yield and take the next step to increase power yield.

2. What are its shortfalls?

The research we are summarizing is detailed and highly scientific, making it tough to regurgitate in "common" terms.

3. What did you learn about proposal writing?

Proposal writing requires extensive research prior to writing and a clear idea of what you are trying to convey.

4. What did you learn about interdisciplinary teamwork?

Working with people from different fields may be challenging because each discipline has a preferred writing style, etc. However, having different backgrounds gives multiple perspectives to a problem which can lead to a deeper understanding and a well-rounded project.

5. What challenges did you face re: writing and teaming?

Some of the topics within this proposal, especially discussion on the work of Dr. Pearce, is quite complex and therefore difficult to explain to a general audience.

6. How did you address or negotiate those challenges?

During peer reviews, we discussed with the reviewers our explanations of terms and other technical passages. This helped us to refine the sections with a more general audience in mind.