Analyzing Solar Power Maintenance in the Madre de Dios Region

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Introduction

Solar energy is a hot commodity all over the world. Developing countries similar to Peru have heavily encouraged the growth in the use of solar panels. Peru faces many obstacles as a large part of the population lives in difficult areas to reach with electricity. To counter this the government sponsored people who are out of reach of electricity to have access to electricity through installation of solar panels. In Spencer Butterfield's study, a previous intern at Finca las Piedras, he noted how the government did well with initial funding of the solar panels, yet when it required maintenance both the government and the private company hired to install the panels were difficult for many people to contact (2021). Since this study, there has been a boost in interest in solar energy and even people with access to the electric grid have been choosing to have solar panels installed. This study aims to show how different aspects of the community use and maintain their solar panels. The sections of the community this study aims to dissect are a remote research center in Finca las Piedras and the local community in Monterrey.

For this study, knowing what solar panels are, how they operate, and what good practices for maintenance are is key. To start off, solar panels are receptors that translate UV rays from the sun into electrons that can be used for power. Each photovoltaic system, or solar panel, is made up of many solar cells which are made up of different layers of different chemicals. Research done at the University of Louisville shows that the general format for a solar cell is a perovskite layer that absorbs the sunlight and outputs electrons, surrounded by transport layers that will move the electron to the electrodes in the gold layer, surrounded by encapsulating material (Lavery et al., 2016).

This solar cell is then multiplied and combined into a much larger solar panel. In the solar panel the solar cells are protected on all sides through layers of encapsulant. On the top side it is then covered in glass and a frame, while on the back it is connected to a structure through its back sheet and connected electrically through the junction box.

The junction box is then connected to the other solar panels in either a string set up (Figure 3) or directly into the charge controller in a micro set up. The charge controller then disperses the energy into the batteries and into an inverter which then provides power.

When you look at the full system there are many different aspects of the solar panel that need upkeep. First, the solar panels themselves need regular care. In order for the solar panels to get the maximum sunlight it is important that they are unobstructed from the sun. Whether this be trimming back trees that are in the way, or cleaning dust, leaves, and other particles off the glass cover. The efficiency of the solar panel can drop up to 50% after just a month of not cleaning it (Myyas et al., 2022). Next, the connecting wires between each part of the system are vital to keeping the system running. If one of the wires gets wet or fries, none of the power generated by the panel will be useful. Going further, the charge controller should be regularly checked to ensure everything is running smoothly. This will be the way to find out if something is wrong or needs attention. Moving on to batteries, batteries tend to have a short lifespan. There has not been much improvement to the engineering of the battery so it will generally fail first in a system like this. There are studies being done to see what material for the anode of a lithium battery will operate the best (Chen, Thapa, & Berfield, 2014). In contrast, it is uncommon to see an inverter break, however in order to fix it the original company from which it came must be called (Fields, 2022). The best way to keep anything from breaking is to monitor the electricity being used.

Another aspect to consider is the environmental factors in the Madre de Dios region. This area is surrounded by the Amazon rainforest which could impact the usability of the solar panels. With the great number of birds overhead there is a high likelihood of droppings marring the surface of the solar panels (Sisodia & Mathur, 2019). Along those lines there are plenty of airborne pollutants that disturb the access to light the solar panels get. With the farmers and cattle ranchers burning hectares of trees the air has been filled with smoke and ash. Deforestation has also caused an increase in dust formation and accumulation from around the world (Li et al., 2021). Particles such as ash and dust when covering solar panels are referred to as soiling. The effect on the panels due to the soiling is up to 18% deficiency (Sulaiman et.al., 2011).

With the climate in the Madre de Dios region, something to consider is rainfall and how that impacts the need to clean solar panels. In the months May through September the rainfall in the region is consistently low averaging around 250 mm between three research stations (Canas & Waylen, 2011). In the same study the research station in Puerto Maldonado showed a maximum amount of rain to be 250 mm during those months. Even though the area itself is a tropical climate, the rain is not common during these months, but even looking at the eight other months of the year one should not rely on rain as a source of cleaning. A study found that rainfall cleans less than 1% of dust off solar panels (Şevik & Aktaş, 2021). Rain tends to have little to no effect on small particles however they do clean the larger ones well (Appels et. al, 2012). This being said, rain will create a positive impact while the water droplets remain on the solar panel surface due to the refractive quality of the water (Del Pero, Aste, & Leonforte, 2019).

This study aims to show how much tropical rain seen in the Madre de Dios region cleans the panels compared to cleaning them. The way the panels will be cleaned will be simulated on what the general population in the Madre de Dios region would reasonably be able to do themselves. While there are much higher tech systems that work for different applications, as seen in the study done by Farrokhi Derakhshandeh et. al., this study will focus on the feasible option for the center (2021).

Methods

Community Feedback/ Spencer's Follow-Up

As there are many members of the community using solar panels, gaining their perspective on the cleaning methods they use on their solar panels. The questions to be used in the interview are listed below:

How many solar panels do you have?
What kind of panels do you have?
What do you use your electricity on?
Are you satisfied with the amount of power you are getting?
Do you have another source of power?
Where did you get your solar panels?
Have you needed to repair your panels? What broke and how frequently does it break?
Do you clean your panels?
How do you clean them?
How often?
How difficult/expensive is it?

It will also be requested if they are comfortable with pictures being taken of their set-up.

Cleaning Project

For this study, data will need to be collected before any rainfall or cleaning takes place. The data that will be compared will be the voltage produced by the solar panel throughout the day. There will be two sources of data for collection, one is a single solar panel that is at ground height (Figure 4), and the other is a string network of 12 panels (Figure 5).

For the single solar panel, a multimeter was used to find the voltage the panel produces throughout the day over a week's time. The first week of collection was with the panel in the untouched dirty state to set a control. The data was collected throughout the first two weeks tracking rainfall as it came. After the two weeks of collection, the solar panel was cleaned using a rag, an extension rod, roughly 18" of string, and a bucket of water seen in Figure 6. The water used for cleaning was collected from the water available on sight to keep the study realistic. This water is pumped from a well into a water tower then output through a faucet. Soap was intentionally not used as studies have shown soap to leave a residue behind that negatively impacts the solar capabilities of the panel (Dutta et. al., 2022). After the panel has been thoroughly cleaned another two weeks of data collection on the voltage produced was collected.

For the system of twelve panels, they will undergo the same procedure of two weeks' worth of data collection, however the way of collecting the data will differ. Rather than using a multimeter, the charge controller will be used to calculate the voltage being collected by the panels. For the setup there are two charge controllers with unknown amounts of solar panels connected to each, so the total amount of volts will be calculated with each collection. In the image below the controller on the left shows 53.5 volts being produced while the controller on the right shows 61.4 volts, therefore the recorded value of the volts collected is 114.9 volts.

The other values seen in the image will be noted as well including the solar panel watts, the battery percent, volts, and amps. All of these values will be noted in a chart similar to the one seen below for each day. These values will be combined into a line plot of voltage over time for each week of study.

Results

Community Outreach

In this study there were a total of five interviews collected from local members of the community who own solar panels. The majority of which were located in the neighboring town to Monterey simply because solar panels were more popular there. There was one study in a concession in Monterrey that was farther from the road and unable to access the electric lines. The number of solar panels each family had ranged from 2-4 panels. Each person interviewed was able to give an estimate of what they believed to be the voltage of their solar panels seen in Figure 8.

Of the panels viewed, half of the panels were on a separate structure while the other half were placed on the roof of their house as one family had one of each. Of the population studied, 80% were happy with the power received from the panels, the remaining interviewee had a very small system. Only one family used a different source of electricity, a generator, at the time of the interview. Another family was looking to get a generator as well. There was only one family who got their panels from the government program and the program sends people to clean their panels and do repairs once a month. As for repairs for everyone else, 60% of the families said they need to regularly change the batteries once every 3 months, but no other repairs were needed. The other 40% did not know or had just recently gotten the panels and have not needed repairs yet. When investigating the usage of electricity the main use was to power lights seen in Figure 9.

In the study 60% of the studied group clean their panels, another family indicated that they would, but the panels are new and haven't needed cleaning yet. There was a mix of structures, notably the family with the highest reach cleaned their panels. All the families that cleaned it used a rag and water, one with a long stick to reach the second story roof the panels were on. Each person who cleaned their panels found it to be easy and to not cost much.

Cleaning at Finca las Piedras

For this study 10 days of data were collected before and after cleaning. At each reading the values from the right charge controller were read, then the left battery, followed by the singular solar panel. A total number of 3,324 values were collected throughout the day.

The results of taking measures throughout the day for the volts received by the solar panel have a slight increase after cleaning in the times from 5 to 7 am and stay along the general line throughout the day showing that it was in fact an upgrade done by cleaning the panels rather than a shift in morning to night sunrise changes (Figure 10). The maximum voltage received before and after were 175.4 and 176.7 respectively.

There are two main types of systems that we have here: a string system and a micro-system. The string system is seen in the twelve panel system where all the panels are connected amongst themselves before connecting to the charge controller and the batteries. The microsystem is seen in the single panel as it would be directly connected to a battery. Below the systems are compared to one another with how many volts they produce per panel.
The battery percent increased significantly faster after cleaning. This is extra impressive as the load on the battery was very different from before and after cleaning as after cleaning had higher loads

(Figure 12). Both consistently reach 100% by 11:00am. Before cleaning had a minimum reading of 63% while after cleaning had a minimum of 66%.

The current in the battery also increased significantly with the clean panels. The only notable time when the after-cleaning amps were lower was at noon and at four pm (Figure 13). The maximum amps collected were 59.1 amps before cleaning and 53.4 amps after cleaning. This shows that while the maximum value was higher before cleaning on average it still improved greatly.

The watts measured from the panels decreased. The maximum value reached by the before cleaning was 1564 watts, more than twice the maximum from after cleaning of 705.2 watts.

Values were also collected in ten-minute intervals once in the morning and once in the evening before and after cleaning. First looking at the voltage, the graph below shows the total volts collected in each of the four readings.

The total volts collected show an increase in the morning collection and a steady night decrease.

The different systems were compared to see how different a micro and string set-up are when it comes to volts received per panel as seen in the figure below.

The graph shows that the before and after cleaning had little effect on the night readings. The difference between the micro and the string set up was clear throughout. The string setup did increase its efficiency after the cleaning as did the micro system for the morning readings.

Moving on to the solar wattage collected from the mornings and night.

The figure shows significant increase in both the morning and night after the cleaning took place. The decrease in wattage received at night before cleaning was more exponential compared to the gradual decline of the after cleaning measurements. The opposite can be said of the increase from the morning readings, the after cleaning measurements exponentially increased rapidly while the before cleaning measurements were more gradual.

Moving on to battery values, the values did not align up with the hypothesis.

The graph shows a generally higher battery percent before the cleaning for both the morning and night. At night the before and after cleaning follow the same path and are a shadow of one another. The morning readings of the after cleaning started significantly lower than the before cleaning, however it caught up quickly and continued its steep incline much quicker than the readings before cleaning did.

The graph displays a large increase in battery amps in the morning after cleaning when compared to before. The night values remained similar with the before cleaning values coming slightly on top.

Looking into solar visibility and voltage you can see a major increase at 5% then a relatively stable line (Figure 20).

This was a theme throughout the other calculated values. Only wattage showed any relative trendline as seen in the Figure below (Figure 21).

Discussions

It was fantastic to see how many members of the community were well versed in the maintenance of their solar panels. Every family member that was interviewed showed high levels of interest in their solar panel system. They could tell me an estimate of the voltage produced right off the top of their head and knew where they were from. The overall satisfaction was high which goes to show that the solar energy is working well in the tropic climate for their family needs.

When looking at the family who used panels from the government program studied by Spencer Butterfield, the support they are receiving is much better than was hypothesized. The family had a pamphlet that they kept hung on their wall for easy reference. The pamphlet gave a comprehensive list of do's and don'ts for how to use the panels along with general information on how to care for it. On top of they the program sends people out regularly to do maintenance and clean them. While the government program is doing a good job of keeping up with the panels, the people I interviewed seemed to know the least about their panels. As it was only one family it is hard to tell if this would be a trend or just one uninterested family, but this could be because the panels were given to them and rather than sought after. They were satisfied with its power production, so if nothing else they are content to have the energy. Given that they were so far remote that they didn't have any other options, the program is very effective for their needs.

The interview of the house with the generator was at a facility of multiple houses that often host biologists that is far enough away from the road to not have access to electric lines. In general, they said they didn't need to use the generator often, but it was good to have for when it was rainy or cloudy. The family did not talk of the government program but instead discussed how they purchased their panels in Lima and brought them in.

As for all the other interviews conducted along the main road, using solar energy seems to still be a high desire. With the exception of the one house with the small panels, everyone was content with their power produced using only the panels. Dissecting this anomaly, one thing that stood out was that the owners had to clean their panels more frequently. They would clean once a week or whenever they needed more energy. As the structure they were on was within easy reach, cleaning was no bother. It could be that since the panels were easier to see, they were better kept up with in regard to cleaning when compared to panels on the rooves of the houses, however there needs to be more testing before that can be proven to be true.

It was against the hypothesis that the most difficult panels to reach were one of the ones that were cleaned. The height of the panels did not deter the users from cleaning them. The type of structure also played no role in if the panels were cleaned or not as those who cleaned their panels had an equal amount of roof structures and structures only for the solar panels. The difficulty was unanimously low so there were no changes between structures or height.

Based on these findings it would be beneficial to local buildings to be using solar panels as long as they are a good size. It is important to know what you intend to power with the solar panels when looking into what kinds to purchase. If the panels are meant to power a washing machine, a water heater, and a water pump system you will need a much larger system than if they are meant to power two lights. Cleaning their panels is a good practice and is a habit that should be adopted by all solar panel users, especially when the soiling is hindering the energy produced. Overall, the practices of solar panel users have been aligned with the best practices for upkeeping them so they should continue as they are.

In the tropical rainforest climate, while there can be large amounts of soiling over time, cleaning the panels had a much lower effect on the usefulness than was anticipated. Many factors could contribute to the values portrayed in the graphs. For instance, there were more rainy days in the pre-cleaning study group compared to the post cleaning making the ranges wider. The electrical load on the system was fluctuating throughout the post- clean study group potentially making the effects less than what they would be. The charge controller does not read the load taken from the batteries as it was not set-up to do so potentially making the battery amperage reading and battery percentage values incorrect. This being said, there was no changes to the system during the process so they will all be consistently inaccurate. The total power available (watts) seems to be the only thing that was affected by the influx of power use. Even the power in the morning was generating very quickly and only showed lower levels during regular usage hours from 8am to 3pm.

Now, while the results are less dramatic than anticipated, they are still not to be discounted. The increase in the morning from around 5am to 7am is across the board a large increase. While throughout the day and at night it stayed relatively similar this indicates that despite the small changes in sunrise/sunset time changes, the results have been steady and cannot be written off by that. The voltage showed a 40% average increase at 6:00am, the battery percentages have over a 10% increase over 6am-7am, and finally the current increased quicker until reaching an average of 10 amps more at 10:00am than before cleaning.

With the amount of buildup and residue that was on the panels prior to cleaning, it seemed to be a miracle that any power was generated. The cleaning supplies were not to lab standard with the water having a high presence of soil from the well it was pulled from (Figure 22).

With this in mind the data collected shows some increase but not as much as expected for the amount that was cleared off. This could possibly be attributed to the cleaning supplies used along with the variables mentioned before. It is general practice to clean solar panels using de-ionized water likely to eliminate any minerals in standard water to hinder the study (Chaichan et al., 2015; Kumar et al., 2011; Anderson et al., 2010).

The morning and night readings showed more improvement in general that aligns with the hypothesis. Consistently each value was higher in the mornings and showed little to no change at night showing that the increase is a direct result of cleaning the panels.

When looking at the battery percentage, the value is only an estimated guess. As the charge controller does not show the load being taken from the batteries it is difficult for it to compute the correct battery percentage accurately. The equation the charge controller would use to find the battery percentage is seen below.

(L= C/I#(1))

Where L is the battery life, C is the battery capacity, and I is the load current. With the potential inaccuracy in mind, the battery percent is still a value heavily relied on as it shares good insight on the voltage coming into the system.

When looking at the voltage per panel on the different systems, the microsystem is consistently twice as good as the string system (Figure 9 & 14). The difference between the string and micro-grid setup can be supported by the conclusions made in Domenech's team study (2014). Micro-grids are known for being much more efficient. There was also a slight difference in solar angle between the panel system types.

It was against the hypothesis that the weather had little effect on the voltage when compared to the time of day. With this being said, the time of day is a very important aspect when it comes to the panels. The angle of the panels and how the sun hits them can heavily impact the production of solar energy (Yunus et al., 2020).

With the bump of energy available in the morning the research center will be able to get more energy out of their day. Big energy usage times like when the water is pumped could occur earlier to allow more sunlight to rebound the large drain. The water could also be pumped at the high peak times of the day to have the energy refill while it is being taken. Tracking the energy throughout the day allows for the staff to know what battery percentages or wattage is normal during different times of the day so when it is off they will recognize that something has happened and are able to take action.

Considering the effects of this study, the research team at Finca should consider biannual cleaning. With the great effort it took to clean the panels, it is recommended to look into better methods or reinforce the structure to better support the weight of the ladder and a person cleaning. Further testing should occur to see what methods of cleaning the solar panels work best for the system.

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