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Photovoltaics in Eastern Kentucky: The Feasibility Study Of Abundant Renewable Energy Resources

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Abstract

Photovoltaics (PV-also called solar photovoltaic devices) are used to harness the power of the sun via the electronic process that occurs within semiconductor cells. The solar energy is absorbed by the cells, which causes the electrons to break away from their atoms, allowing them to flow within the material to produce electricity. This electricity will become the renewable energy for Kentucky, as the generation of coal will but come to a stop within the near future. Like Denmark who is running on 100% renewable generation we must stride to become fully operational on solar. By systematically studying renewable energy resources, in particular, solar energy for the application of photovoltaic panels in Eastern Kentucky. By analyzing data from our PV cells at Morehead State University designed to follow the direction of the sun for optimized output and by incorporating MPPT charge controllers, we have constructed a maximum power algorithm that performs best for the location. Utilizing these, measurements of daily electricity production in comparison to the average power needed for household use has validated our research. With the advancements in solar cell technology what was once impossible is now reality, as solar power can easily power this region based on our data. Knowing this, being a prime location, the researcher can now push to enable the advancement of renewable energy production and become less dependent on fossil fuels, thus creating an infrastructure that will run off solar power.

Keywords: Solar Power, Renewable Energy, Morehead, Eastern Kentucky

1. Introduction

Energy for the future has taken many different faces, however, as it is known it won't and cannot be the non-renewable sources of energy used in our present modern society[1]. As of today, many states are taking this leap to prepare for the future before it has become too late. However, while those are beginning this leap there are just as many holding back in this case, Kentucky is falling behind on this current renewable trend and by falling behind they are doing nothing[2]. This trend of course, is switching to renewable resources compared to the non-renewable counterparts, as well as, overall trying to become a greener country for the world. By doing nothing in this case primarily Eastern Kentucky, is not preparing for the inevitable shortage of our most precious resource that has been depended so heavily upon these many years, coal[3]. While it might not be gone now or within the next few years, it will be depleted in the foreseeable future. Due to the sheer size of the coal industry Kentucky has also opted to never join the regional agreement to cap greenhouse gas emissions[4]. Thus, along with West Virginia is one of the worst offenders of carbon dioxide emissions do to their heavy use of coal.

So, what's the solution? While Kentucky currently does not have a renewable portfolio standard and its electric utilities do not generate electricity from solar power[1]. This can and needs to be changed to develop into the needed solution. Kentucky is a prime location for solar collection, however, is being held back by legislature and how the state is currently being run[2]. All other forms of energy are being pushed away because Kentucky only goes with the cheapest option for energy that can be chosen[3]. This being coal, as it has kept Kentucky being the cheapest price for power out there[4]. While, Solar isn't the cheapest energy generator as of right now it is still figuratively nipping at the heels of coal as the development and research are making it more efficient and better cost wise every year due to advancements in the technology[5]. This doesn't have to be a quick transition, something like this could never happen overnight. This transition isn't the type where the opposite steps aside while the other takes over. They begin by working in tandem, but the infrastructure to do this needs to be built now and advance over the years that it shares with coal. So as the infrastructure is slowing building it will share the job of energy production until it can take over and become the sole generator, thus completely dampening Kentucky's dependency on coal[6]. This building of an infrastructure will not only push for Kentucky to grow along with the rest of the country, but will grow the economy as it will create new potential jobs that are being lost due to the slowing down of coal manufacturing and increasingly because of onerous regulations that the Environmental Protection Agency is promulgating to slow or roughly stop the production of the coal industry.

2. Proposed Approach

Hardly anyone knows of the potential that shines on "My old Kentucky Home"[5]. This is what has been set out to become substantiate through this research to finally show just how much power mainly Eastern Kentucky receives on a routine daily basis. By strengthening this information, it will enlighten those who arbitrarily believe that it can't be done. To get this data, measurements of the day to day power generation needed to be collected by means of solar or photovoltaic arrays. Then with this data which will show promising results, a comparison to the normal household electricity needs can be created. This comparison will then show that solar power can not only power the normal household of Eastern Kentucky but be used to power most of the area, if the infrastructure was further built upon for the area. As well as, show that solar is an efficient option that is the only option for the future of this area[6].

3. Eastern Kentucky Solar Resources

First, I needed to figure out if this location gets enough sunlight or solar rays to even can become a decent location for photovoltaics. Considering this an evaluation was made due to figuring out what each state in the United States gets and comparing it to other countries that have already applied solar power into their infrastructure. These countries build a probable case as to if Eastern Kentucky can do the same and can pull it off[5]. The best comparison to show a complete distinction as to why this area is a perfect locale, is when you bring in Germany. Germany is currently running on mainly renewable resources which of course includes solar power. This region when compared to the United States is equal to the solar low of Alaska which is the worst state for solar power potential[7]. While Kentucky is sitting a pretty good mid ground for solar potential, being much better than Alaska and Germany combined. When looking at this, Eastern Kentucky seems to be really promising so this research and should without a doubt yield impressive results[8].

To start off an evaluation of what was needed to complete this research was done. Not only did was there need of standard solar panels, but there would be the need to go one step further. So, after putting that to thought we designed and built our own two-axis tracking system so that we could optimize our input of solar rays coming to these arrays. This tracking system triangulates the most efficient tilt and angle to be at as per the suns location due to the time of day[9]. By using a light sensor connected to our own system it can adjust the solar panel off two-axis automatically to follow the path of the sun thus collecting the maximum amount of energy possible[10]. By doing so, we can increase the total daily collection by about 40%. This being compared to a fixed surface is shown in the below fig. 1. As the comparison shows the two-axis tracking has a complete increase on every reading throughout the day but is less of an increase at the peak of the sun movement around noon and the start/end of the days because there is less to be increased at those times. Since the fixed point is getting its best and worst readings at those of the day. Thus, showing that a two-axis system is the only tangible way to produce an efficient photovoltaic system here is Eastern Kentucky[11].

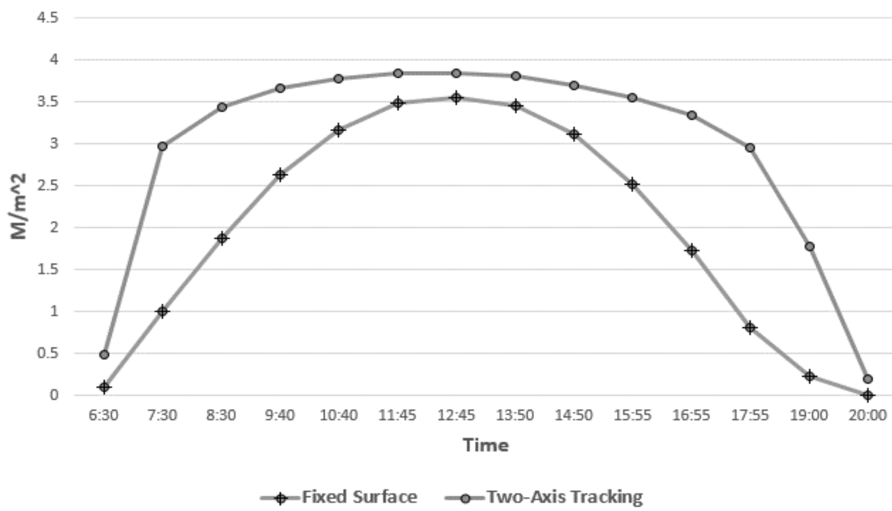

Figure 1. This figure illustrates the comparison between a sun tracking solar panel system that is designed to follow the sun for maximize output and a normal fixed in place solar panel system aimed towards the rise of sun.

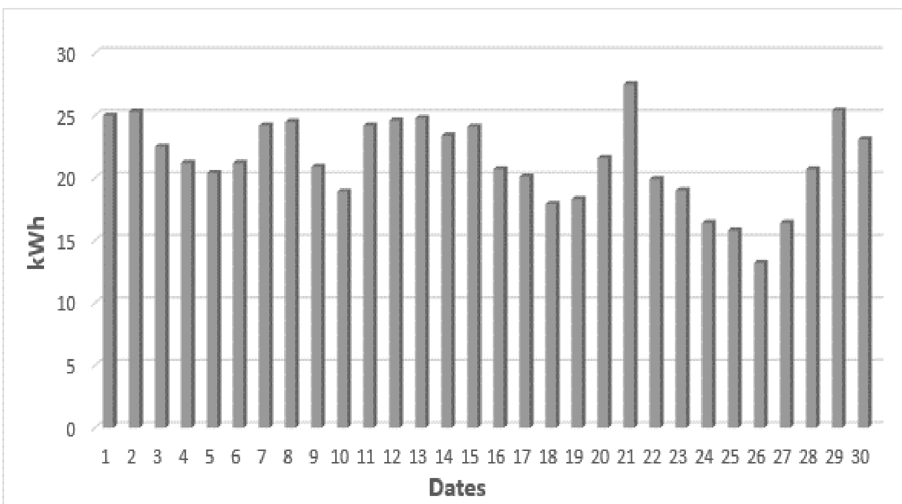

Figure 2. This figure illustrates readings from solar panel within Eastern Kentucky for the month of September.

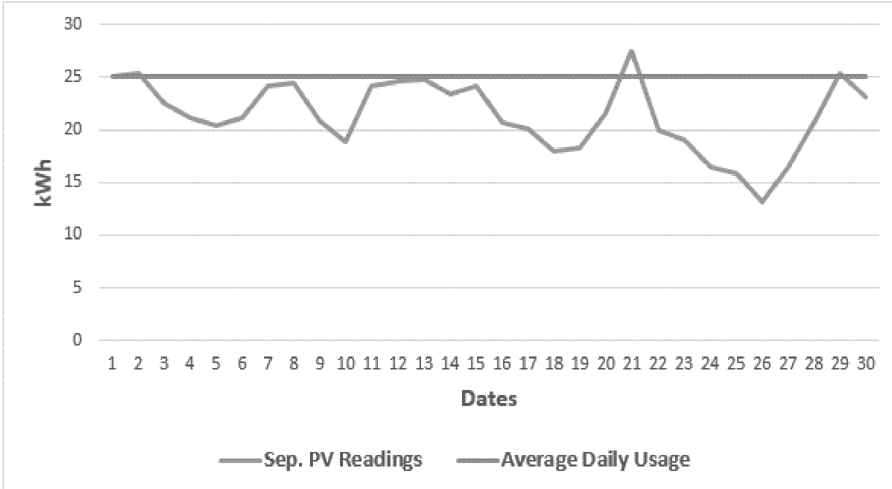

Figure 3. This figure illustrates readings from figure #2 being compared to the daily usage of electricity in the average household which is a static value.

Provided using a 235 Watt (or a 213 PTC (PVUSA Test Condition) Watt) array measurements have been taken, over the past months to collect or arrange a basis to go from. These readings were gathered using only a standard fixed panel array with no functional way of following the sun. The author does not have an advanced MPPT (Maximum Power Point Tracking) system to push for a more efficient collection of power in the batteries. With the basis, it shows very good results as the data is well within what we expected to find here in Eastern Kentucky[10]. Over 600 kWh as a total was being generated just within the 30 days of September. That total by calculating out the data, has a daily average of over 20 kWh (As seen in Fig. 2). Going by this it wouldn't take much to power a normal household[11]. Taking into consideration every household is far from the same, using an electricity bill from the same month, a total of 753 kWh was used that month which is a 25.1 kWh average for each day. Now by incorporating that with the readings from Fig. 2, we get Fig. 3 where even with just a 235 Watt array the readings can reach equal to and even over the average daily usage of a household here in this region on some of the better days. Through some small calculations, we can find that it would only take an array of 325 watts to provide a solid power generation that will go above this average and can keep a house functioning with electricity even on the worst days of the month.

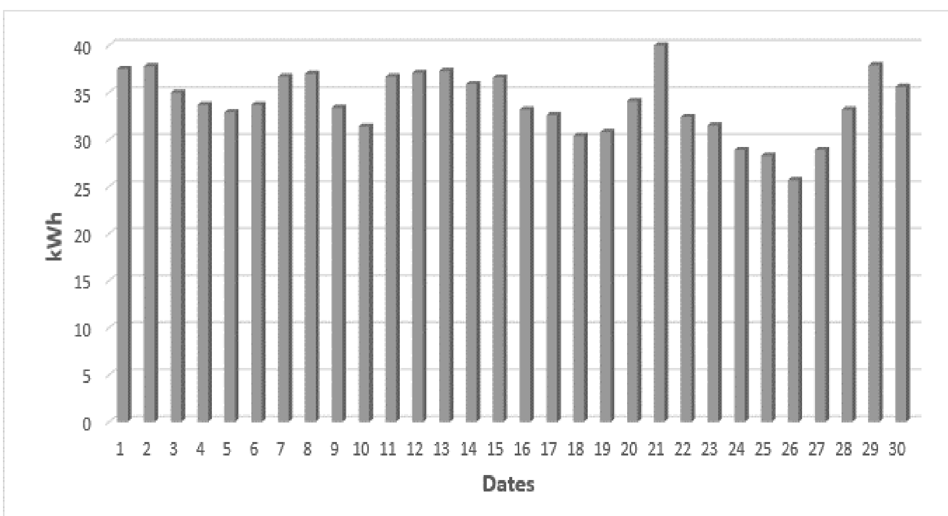

Figure 4. 325 Watt Panel. This figure illustrates using the readings from figure #2, calculations to show the potential of a 325-watt panel for the month of September in eastern Kentucky.

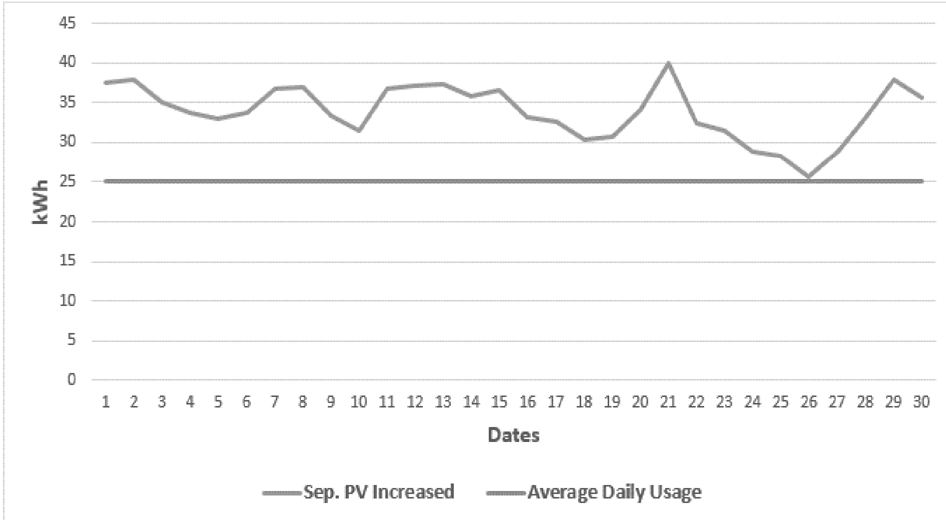

Figure 5. This figure illustrates comparing the daily usage of electricity in the average household (static value) to the now calculated potential of a 325-watt panel.

Continuing that last point, here in fig. 4 it shows just how much 90 more watts are compared to the last panel in fig. 2. Being a theoretical calculation but based off the real world tested data, it comes out to be a 12.5 kWh increase to each of the days we had readings for. As it is always good to have more power than necessary as a safety net using a 325 Watt system would be enough to power a household in the eastern Kentucky area. A 325 Watt PTC (PVUSA Test Condition) PV system would be producing an average of 32.5 kWh a day or a 975-kWh total for a month of 30 days. This is well over the total used amount but would cover days that are not so generous for solar collection. The winter months of the year tend to be the least productive months of the year. When compared to the household average covered in fig. 5 the 325 Watt panel system is well enough to power it.

4. Future Plans

As for the future, they include mostly of taking all this data we have collected and creating our own system here at Morehead State University to have a true test location and to have full control of the elements that could stop us from reaching the end point of proving solar is the only choice for Eastern Kentucky as for a renewable resource option[12]. To create this system, we already have everything needed here in our labs such as the two-axis tracking system and the panels. Along with that, we while need to include an MPPT (Maximum Power Point Tracking) charge controller to maximize our output of energy being coming from our arrays. This technology now comes with most standard quality inverters but we want to take to another level. A normal inverter equipped with an MPPT can extract all the energy possible out of a set of panels by adjusting the voltage to always suit the inverter's preferred input range. With this in mind, the development of our own MPP algorithm to do not only the standard operation of the inverters, but to be able to efficiently do most of the work for our system. This includes minimizing the partial shading effect which is the effect of in a string of panels if one or a few panels are covered by shade in a normal system this would flatten the output of power and thus causing a shortage of power to whatever you are trying to supply it for[13]. By minimizing this with an MPPT algorithm you can take in effect the fact that if even with the complete set of panels you can only output so much at one time. However, if you apply the algorithm if those one or more panels get covered in shade it will use the others to backpack them and still can output the same amount of power by just taking more from the others that are not being shaded. This can and will be done by developing it with by-pass diode, shaded panel tend to operate in negative due to higher Iph from series connected other cells so this algorithm will determine Iph at each panel and thus switch the by-pass on if the need arises[14]. The algorithm will just about look like equatioin 1

$$F(I_{pv}, V_{pv}, T_k, G) = I_{ph} - I_{pv} - I_{o1}\left[exp\left(\frac{q(V_{pv}+I_{pv}R_s)}{N_s A K T_k}\right) - 1\right] - \frac{(V_{pv}+I_{pv}\,R_s N_s)}{R_p N_s} = 0 \qquad (1)$$

Once the author hasfinished this algorithm and have arrived at our desired solution the author will then push to on to implementation with our currently created two-axis system. This will allow us to actualize a field test of designed solar collection tracking system and newly developed MPPT to create our own set of data that can be further analyzed to produce the results needed for this currently solar deprived location. While most of our current calculations are half theoretical and half tested with our own system the author will reanalyze for future data to compare for percentage increase to our tested amounts to see if the author was correct in understanding. that this region holds quite a large potential. Lastly, the author will use this to exhibit that newly developed efficient photovoltaics will fully power this region for whatever its needs and that the populous should stop hiding behind coal.

5. Conclusion

The author started with a question, could solar power be the future of energy in the Eastern region of Kentucky. This needed to be finally sought after due to the lack of any improvement for this location. First, the author gathered the required data to provide ourselves with a proficient amount of resources to be used for further calculations and to build a basis to go on. This was done with a 235-watt array with a fixed in place axis. By taking this gathered data and comparing it to the average household powerusage it could be deducted that while being close to powering it a bigger array was needed. With this the authorcould now move forward into what the author figured out. By using the real field collected data and just increasing the size it was found a 325-watt panel was all that was needed to power a household without having to improve anything. Thus, allowing us to calculate how much could improve this system by upgrading to two-axis tracking and a MPPT algorithm which both immensely increase the amount of powere that could be collected compared to a normal system.

In conclusion, it can be deducted that Eastern Kentucky is without a doubt a prime location for the use of PV as a production source of renewable energy. Through the test condition measurements of our photovoltaic systems, the validation is now legitimate. This can advance the almost stalled point this state has reached when it comes to energy generation. Coal doesn't have to be the sole resource the author depended upon and it no longer should within the foreseeable future. This area now has the option or way out it has been needing before the problem arises. Technology has reached the point an infrastructure needs to be developed and built to better this area as a hole and further better our nation into becoming more renewable and self-sustaining.

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