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Conversion Efficiency of Solar Panels

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Abstract— ***This work presents an in-depth, practical approach to ascertaining the efficiency of monocrystalline and polycrystalline solar panels. Solar power is gradually making its way into the domestic and industrial space, replacing older (less environmentally friendly) sources of power. Their efficiency and other performance parameters are worth analyzing so as to establish methods of improving existing solar technologies. Various tests were conducted to determine the energy conversion characteristics of two types of solar modules. The results of the test for a duration of five days revealed that the maximum and minimum efficiencies for monocrystalline panels were 33.05 percent and 3.36 percent, respectively; for polycrystalline panels, they were 31.44% and 1.13%, respectively. This gave rise to average daily efficiencies of 19–22% and 13–20% for monocrystalline and polycrystalline modules, respectively, which are within the industrial-rated efficiency values obtainable for both solar panels. The reason for these obtained results may have arisen due to the availability of sunlight for most of the period of the experiment. However, suggestions were made at the end of the research to further improve the already established efficiencies of solar panels.***

Index Terms— ***Solar efficiency, monocrystalline, polycrystalline, photovoltaic, conversion, temperature, solar irradiation.***

I. INTRODUCTION

There is currently a prevailing energy crisis across the globe. This fact is captured by Henry Aribisala, in his thesis on “Improving the efficiency of solar photovoltaic power systems” [1]. In this thesis, he pointed out that, there is an alarming rate of depletion of the major conventional energy resources available to man, such as Coal, Natural gas, and Petroleum.

But to think that the depletion of the energy sources is not enough, there is also a continuous environmental degradation caused by the processes involved in harnessing energy sources, making it a matter of urgency to invest in renewable energy resources, like solar energy. Solar energy can power the future sufficiently without any fear of experiencing environmental degradation through greenhouse gas emissions [1].

Furthermore, amongst other renewable energy sources like hydropower, wind power, etc, solar energy is one of the most highly-regarded sources of energy in the world, and this is because of its massive availability, cost-effectiveness, and human and environment friendliness [2]. Also, the application of solar energy in electric water heating, power generation, and air- conditioning [3]. is at the core of solar-based technologies that are fast growing worldwide.

Solar energy can be regarded as the anchor behind other forms of renewable energy sources. It anchors wind power in which the movement of air is due to the heating effect of the sun on the atmosphere. In the same manner, it anchors hydropower where the hydrological cycle is being controlled by the sun. In general, heat, electrical energy, kinetic energy, and chemical energy can be generated via the conversion of solar energy [4].

In essence, the energy potential of the sun is immense. But despite this limitless potential of solar energy resources, harvesting it is a major challenge. The main reason is because of the limited efficiency of the array cells [1].

In addition, the research of Green and Martin A. on “The Operating Principles, Technology, and System Applications of solar cell”, showed that the best conversion efficiency of most commercially available solar cells is in the range of 10% to 20s% [5]. This figure is pretty far from the expected hopeful range at which solar energy can be harvested. Going forward, although recent breakthrough in the technology of solar cells (solar panels) showcases significant improvement, the fact that the maximum solar panel efficiency still falls in the less than 20% range indicates that there is enormous room for improvement [1].

As solar energy forms the basis of all other forms of renewable energy sources on earth, it is therefore paramount that every attempt is made to maximally harness and utilize solar energy as an invaluable resource. This is an act that will ensure adequate and efficient use of the immense potential of solar energy across various aspects of life. Not only this, but it will also improve PV technologies so that they can be cost-competitive with conventional sources of energy.

Lastly, a recent breakthrough in the technology of solar panels shows significant improvement in how much solar energy can be harnessed. However, as long as the maximum solar cell efficiency still falls in the less than 20% range, there is enormous room for improvement.

Several factors affect a cell's conversion efficiency value, including its reflectance, thermodynamic efficiency, charge carrier separation efficiency, charge carrier collection efficiency, wavelength, recombination losses, and conduction efficiency values [6]. Due to these factors, despite the enormous amount of energy striking the panel from the sunlight, a lot of this usable energy gets wasted as heat.

To this end, this study aimed to analyze the performance of conversion efficiency of solar panels in comparison with already established efficiencies.

II. LITERATURE REVIEW

Solar PV technology is one of the renewable technologies with the potential to provide a clean, affordable, reliable, and scalable electricity system for the future [4]. This growing need of using solar energy lies in the fact that it is very affordable and when compared to other sources, is several times higher than the volume of global energy consumption and it is environmentally friendly. According to a report by the UN World Development Energy Assessment in 2000, the annual potential of solar energy is in the range of 1575–49837 exajoules. This is several times higher than the total energy consumed worldwide at the beginning of the 21st century [7]. Some research experts believe that solar energy may even have greater potential than already seen. For example, [8]. in his 21st Century Energy Sobering Thoughts, claims that the potential of solar energy is more than 13,368 exajoules per hour.

2.1 History and Development of Solar Cell Technology

The journey of solar cell technology began with the pioneering work of French physicist Antoine-Cesar Becquerel. In 1839, at just 19 years old, Becquerel made history by constructing the world's first solar cell in his father's laboratory. This happened after observing the power of solar energy while conducting experiments with a solid electrode in an electrolyte solution [9].

Years later, in 1888, Russian physicist Aleksandr Stoletov built the first photovoltaic (PV) cell based on the outer photoelectric effect, discovered by Heinrich Hertz in 1887. Going further to 1905, Albert Einstein cemented his place in scientific history with a groundbreaking paper explaining the photoelectric effect based on quantum theories, earning him a Nobel Prize in Physics in 1921.

From 1839 to 1904, several scientific discoveries laid the foundation for solar cell technology. These include the discovery of the photovoltaic effect in selenium by W.G. Adams and R.E. Day in 1877, and the creation of a semiconductor-junction solar cell using copper and copper oxide by Wilhelm Hallwachs in 1904.

Furthermore, from 1905 to 1950, the theoretical foundation stage of photovoltaic cells took center stage, as scientists worked to formulate the underlying principles behind PV technology. It was during this time that some of the most pivotal contributions were made, including:

In 1905, as already hinted, Albert Einstein made a breakthrough with his paper on the photoelectric effect, which he explained based on quantum theories.

Jan Czochralski, a Polish scientist, made waves in 1918 with his innovative method for growing single crystals of metal. This method was later adapted to produce single-crystal silicon.

The theory of high-purity semiconductors was advanced by A. H. Wilson in 1931.

F. Bloch's development of the band theory based on single crystal periodic lattice in 1928 was a major leap forward.

By 1948, Gordon Teal and John Little had successfully adapted Czochralski's method of crystal growth to make single-crystalline germanium and silicon, further advancing the field [10].

This period saw the formation of the theoretical framework on which photovoltaic cells would operate for years to come. These achievements paved the way for the next stage in the development of solar technology.

2.2 Solar Panels

The sun is a boundless source of energy, and capturing its radiant power is made possible through the use of solar cells. These semiconductor wonders are designed to convert the sun's energy into electrical power that can be harnessed for our daily use.

A solar panel, also known as a photovoltaic module is a collection of multiple solar cells linked together by conductors made of aluminum, copper, or silver. These panels come in varying sizes and serve as the building blocks for larger photovoltaic systems [11].

Whether for commercial or residential use, solar panels can be the cornerstone for generating and supplying electricity to our world. They come packaged and ready for installation, making it easier for us to reap the benefits of this renewable energy source.

2.2.1 Main Components of Solar Panels

The main components of solar panels are:

1. Solar photovoltaic cells
2. Toughened glass -3 to 3.5 mm thick
3. Extruded Aluminum frame
4. Encapsulation -EVA film layers
5. Polymer rear back-sheet
6. Junction box-diode and connectors

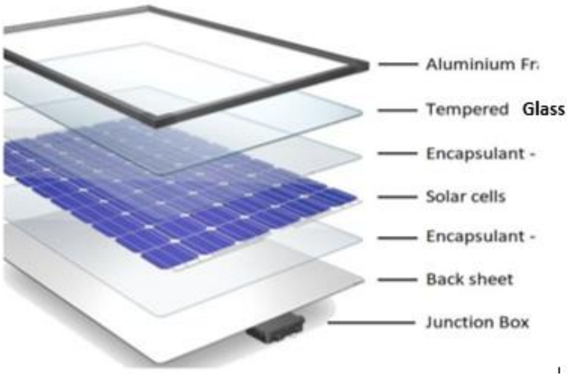


Figure 2.1 Component arrangement of a solar panel Sourced: [1]

2.2.2 Working Structure of Solar Panels Modules

Solar panels harness the power of the sun, capturing its light energy and transforming it into electricity through the photovoltaic effect. The majority of these panels are made with either crystalline silicon cells or thin-film cells based on cadmium silicon.

The top or back layer of the panel serves as its structural support, holding the cells in place. Most solar panels are rigid but have available those with more flexible options, which are made out of thin-film cells. Solar panels have been soaring into the stratosphere since 1958 when they made their first appearance in space.

Their working structure is such that, the solar cells must be electrically connected and connected to the rest of the system, either in series for desired output voltage or in parallel for desired current capabilities. The wires that carry the current away from the panel can contain silver, copper, or other non-magnetic conductive metals. Bypass diodes can also be added to the design or used externally to maximize output from a partially shaded panel.

Over time, innovative designs have emerged, featuring concentrators that focus light onto smaller cells using lenses or mirrors. This allows for the use of cells with a higher cost per unit area, such as gallium arsenide, in a more cost-effective manner [11].

2.3 Types of Solar Cells Used in Solar Panels

The building blocks of solar panel lies in their solar cells, also known as photovoltaic cells. When two or more of these cells come together, they form a solar photovoltaic (PV) array. These cells are the powerhouses that harness the sun's radiant energy and transform it into electricity to fuel our daily lives. They contain materials with remarkable semiconducting properties, where electrons get charged up and flow as electrical currents when bathed in sunlight. There is a variety of solar cell options available. But even at that, the most widely used solar cells are those crafted from crystalline silicon, either Monocrystalline or Polycrystalline, and those made using cutting-edge thin film technology.

2.3.1 Silicon Solar Cell

The world of solar cells is dominated by silicon-based materials, with an estimated 90% of all solar cells being made from this abundant element. The effectiveness of silicon-based cells in converting sunlight into electricity lies in the purity of the silicon used, with purer silicon molecules resulting in greater energy efficiency. Among the different variations of silicon, crystalline silicon is the most common type, composing a staggering 95% of all silicon-based solar cells on the market [12].

2.3.2 Monocrystalline Solar Cells

Monocrystalline solar cells, also known as single crystalline cells, stand out from the crowd with their distinctive color. What sets them apart is the fact that they are crafted from the very best of silicon - pure, unadulterated, and with a flawless alignment of molecules. When reviewing silicon in detail, the clearer the arrangement of atoms, the more proficient the material becomes in transforming sunlight into electrical energy. Monocrystalline solar panels have the highest efficiency rates, typically in the 15-20% range. This high efficiency rate means they produce more power per square foot, and are therefore very space-efficient [13].

To further enhance performance, monocrystalline solar cells are molded into cylindrical "silicon ingots". This inventive design not only adds to their aesthetic appeal but also optimizes the conversion of sunlight into electricity

2.3.3 Polycrystalline Solar Cells

Polycrystalline solar cells also referred to as polysilicon or multi-silicon cells came to the limelight in the solar industry in 1981 [13]. Unlike monocrystalline cells, these cells don't undergo the meticulous cutting process. Instead, the silicon is melted to a liquid state and cast into a square mold, which gives polycrystalline its signature square shape. Though attractive, these cells fall slightly short in efficiency compared to monocrystalline, with a range of 13-16% [13]. This disparity can be attributed to the lower purity of the silicon used in the production of polycrystalline cells.

Figure 2.2 monocrystalline and polycrystalline solar cells

2.3.4 Thin Film Solar Cells

The Thin Film Solar Cell is a rising solar cell in the solar industry, recording explosive growth rates of 60 percent between 2002 to 2007 [14]. By 2011, the thin film solar cell sector was making its mark, accounting for a remarkable 5 percent of the total solar cells on the market. Today, with numerous variations available, thin film cells generally boast efficiencies in the range of 7-13 percent. But the future looks bright for these cells, with a multitude of research and development investments aimed at pushing the boundaries of thin film technology. Some experts predict that upcoming models could see efficiencies soar as high as 16 percent!

Figure 2.3 Thin film solar cells

2.3.5 Amorphous Silicon Solar Cells

Amorphous silicon-based thin-film solar cells have long been the choice for miniaturized endeavors, such as pocket-sized travel lights, trusty calculators, and tough camping gear for remote escapades. However, a cutting-edge process known as "stacking," which involves layering multiple amorphous silicon cells, has led to a surge in efficiency levels, reaching up to a dazzling 8 percent [15]. Although the stacking process has unlocked a higher level of efficiency, it still comes with a pretty expensive price, as a result, is considered to be relatively costly.

2.4 Energy Storage in Solar Panel Systems

For stand-alone solar power systems, storage is a necessary component unless the load demand is equally matched with the availability of the sun. To maintain power at all times, energy storage serves several crucial functions:

1. Illuminating the night with stored energy.
2. Sustain operations during cloudy weather (with the amount of storage needed depending on the location's cloudiness).
3. Provide a cushion during low-sunlight seasons, such as winter, and offer a power boost for devices with high starting currents.

Among the numerous energy storage options, chemical storage in the form of batteries is the most common in photovoltaic systems. Hence, understanding the intricacies of batteries is vital, considering their crucial role in stand-alone photovoltaic systems.

Also, an ideal battery would have limitless charging and discharging capabilities without incurring losses or self-discharge. But in reality, no battery has yet achieved these perfect conditions.

2.4.1 Solar Battery

Solar batteries, also called panel batteries, are essential components for capturing and preserving the sun's energy. Designed to work hand-in-hand with solar charger controllers or inverters, these batteries store the excess energy generated from solar panels, allowing access to it whenever it's needed. Whether you're powering off-grid or hybrid systems, solar batteries ensure that your connected loads run smoothly and efficiently.

During the day, these batteries work tirelessly to convert the direct current energy produced by solar panels into stored energy, and when the sun sets, the stored energy can be easily converted back into usable alternating current with the help of a power inverter. Essentially, solar batteries serve as the perfect partner to help you harness the sun's power and make the most of it [16].

Figure 2.4 A typical deep-cycle battery

2.4.2 Types of Solar Batteries

There are two main types of solar batteries - primary and secondary. Primary batteries operate on a one-way street (transforming chemical energy into electrical energy, but never being able to reverse the process). Secondary batteries, on the other hand, boast a two-way transformation (converting chemical energy into electrical energy and vice versa, allowing for repeated charging).

Beyond primary and secondary batteries, there are also two sub-categories of solar batteries - low cycle and deep cycle. Each serves its unique purpose and benefits within a solar energy system.

2.4.2.1 Low Cycle Batteries

Low-cycle batteries are designed to be ideal for short bursts of energy, but not meant for the deep discharge that a solar panel system requires. These batteries are typically used in vehicles and can handle small surges, however, repeatedly draining them below 20% will drastically shorten their lifespan. When dealing with solar panel systems, it's best to steer clear of low-cycle batteries for solar power setups.

2.4.2.2 Deep cycle Batteries

Deep-cycle batteries are specifically designed for regular, full discharges. These batteries are typically lead-acid based and are the preferred choice for solar panel systems. Unlike low-cycle batteries, deep-cycle batteries are built to handle the demands of powering your home with the energy collected from the sun.

2.4.2.3 Lead Acid Batteries

Lead acid batteries come in two forms - vented (flooded) and non-vented (sealed). At the core of each battery lies a negative electrode crafted from porous lead and a positive electrode made of lead oxide, both of which are submerged in an electrolytic solution of sulfuric acid and water. Designed with numerous thin plates to deliver maximum surface area and current output, lead acid batteries can be fragile and prone to damage from deep discharge. Also, prolonged exposure to deep discharges can lead to a decline in capacity, and ultimately an untimely death, as the electrodes crumble under the stress of repeated cycling.

III. METHODOLOGY

In this section, a holistic approach is used to detail the various materials and methods employed in determining the conversion efficiency of the Solar panels. Real-time measured values of the voltages and amperage generated in the monocrystalline as well as the polycrystalline solar panels under the same loading setup are used to create a plot of the I-V characteristics at different time intervals.

During the tests, major focus was on the following:

1. How fast the charging of the battery will be at different weather condition.
2. The maximum charging current and charging voltage at different weather condition.
3. The actual rate of efficiency from the panels in comparison with already established reports.
4. The total time it takes the solar panels to fully charge the batteries.

3.1 Material/Apparatus Used

1. One 130W/17.52V monocrystalline solar panel
2. One 100W/12.5V polycrystalline solar panel
3. Two 200A/12V of deep cycle batteries
4. Two DC ammeters
5. Two DC voltmeters
6. 10 yards of 10mm cable wire

3.2 Procedure

A simplistic procedural method which can easily be replicated and analyzed for errors has been adopted and is discussed under the section 3.3.1 and 3.3.2.

3.2.1Connection of Solar Panels

The two solar panels (monocrystalline and polycrystalline panels) were tilted to the ground at an angle of 23° and 26° respectively. The monocrystalline solar panel used had a power rating of 130 W while the polycrystalline solar panel had a power rating of 80W. Two 10mm cables were connected to the positive and negative terminals of the solar panels.

3.2.2Battery Connection

Two 12v 200AH deep cycle, valve regulated lead acid produce by Sonnenschein company were used to carry out the test. Each of the battery was connected to the different solar panel using a battery cable to achieve a 13.2v output when fully charged.

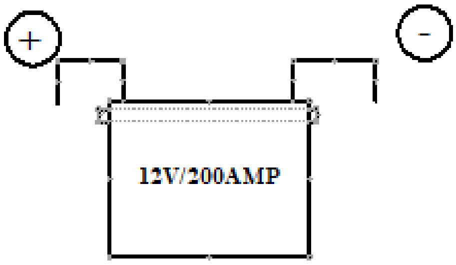


Fig 3.1 Battery block diagram

From the above connection, the total battery voltage is $V_T = 12$ volts

Battery watt hour;

$P = VIH$ (3.1)

Where IH = Ampere hour and V= voltage

$P = 12 \times 200$ $P = 2400$ Watt Hr

Charging hours = Ampere hour of battery/Ampere of solar

Charging hour of monocrystalline solar panel = 200/7.43 = 27H

Charging hour of polycrystalline solar panel=200/4.49 = 44H

Therefore, due to losses along the cable, the battery was expected to be fully charged under 27 hours and 44 hours for monocrystalline and polycrystalline panels respectively.

3.3 Experimental Setup

3.3.1Monocrystalline Solar Panel

In order to compare the monocrystalline panels and the polycrystalline types, a thorough charge analysis was conducted. In this experimental work, the sum total of the electrical energy supplied to the battery from the monocrystalline panel was obtained by measuring the charge properties with volt meters and an ammeter as shown in Figure 3.2. In this setup, two voltmeters (one across the soler panel and the other across the battery) were used to determine the voltage leaving the solar panel and the voltage effectively charging the battery. The ammeter reading showed the amperage of the electrical power generated.

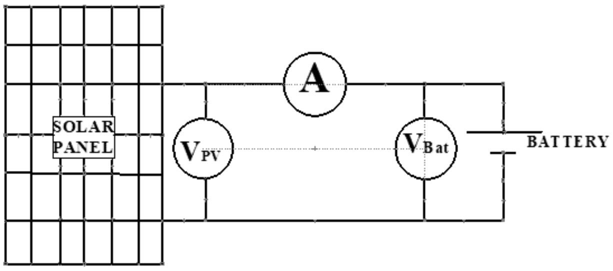


Figure 3.2 Experimental setup of the solar panel

3.3.2Polycrystalline Solar Panel

The polycrystalline panel was also setup in similar fashion as the monocrystalline panels. As such, details such as the voltage across the charging battery, the solar panel and the current within the system were accurately taken to account by the use of the voltmeters and the ammeter. The mannerism of the connection is depicted in Figure 3.2. As indicated, the battery remains at the end of the connection serving as the charging load.

3.4 Measurements and Data Processing

In line with the objectives of investigating the efficiencies of the different solar panel types, measurements and processing of data was done using digital equipment such as a digital multimeter to measure the voltage and ampere where necessary. To ensure the credibility of the data collected, a 5 (five) days period at the rate of one reading every 20 minutes was conducted. The data was documented and tabulated for analysis.

3.5 Complete Connection

Objectively, a wire routing that ensured the conservation of energy using the shortest possible distance between the panels and the other components of the setup was adopted. Its implementation involved the use of 10 mm cables for the positive as well as the negative terminals of the panels. While the positive terminal of the ammeter was corrected to the positive terminal of the monocrystalline panel, its negative terminal to the positive terminal of the battery. This connection ensured that the current in the system was read accurately. Moreso, the negative terminal of the battery was connected directly to the negative terminal of the monocrystalline panel.

For accurate readings, the voltmeter ran across the battery and the panel and their measurement taken at 20 minutes interval. In a similar manner, the ammeter, voltmeter and the battery was connected for the polycrystalline panel.

3.6 Panel Efficiency

Panel Efficiency is the total amount of solar energy that can be converted into actual electricity by a solar panel, under standard test conditions. A more efficient panel takes up slightly less space to produce an equal amount of power than a less efficient one.

Efficiency of conversion (η) is an important metric of system performance. When applied to solar energy conversion systems, efficiency of solar energy conversion (η) is defined as the ratio of useful output power (delivered by the conversion device) to the rated power:

$$\eta = (P_{out})/P(_{rating})\ x\ 100 \qquad (3.2)$$

Efficiency for monocrystalline panels:

$$\eta = (I \times V) / (130) \times 100 \qquad (3.3)$$

Efficiency for polycrystalline panels:

$$\eta = (I \times V)/(80) \times 100 \qquad (3.4)$$

Where I is the current produced by the panel from the rays of sunlight that strikes the panel V is the voltage across the battery.

IV. RESULTS

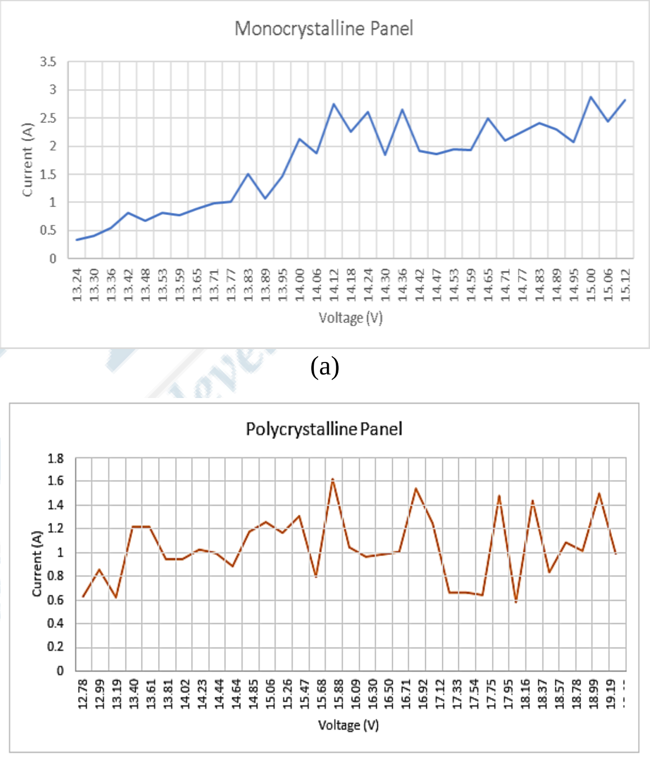
The data collected were recorded in comma separated values (.csv) and several plots generated for the I-V characteristics, and the efficiency at 20 minutes intervals. More emphasis is placed on the efficiencies of the solar panels as this is a cardinal factor for the selection of a solar panel for application in industrial and domestic settings.

The results and analysis are used to ascertain the feasibility of adopting the panels for different applications on industrial and domestic scales for economic and technological purposes.

Due to the bulky nature of the data collected from the experimentation, data from selected days were analyzed and the deductions extrapolated to scale in making well informed judgments of the facts which the result point to. Keen attention was also paid to the effect of solar peak and other atmospheric factors which has consequential effect on the results obtained.

By plotting the values for the five days, various graphs can be drawn to explain the average efficiency produced by the solar panels during the period of study against the time and also the output I-V characteristics of the panels. The following graphs are therefore, valid in explaining the Conversion Efficiency of the solar panels.

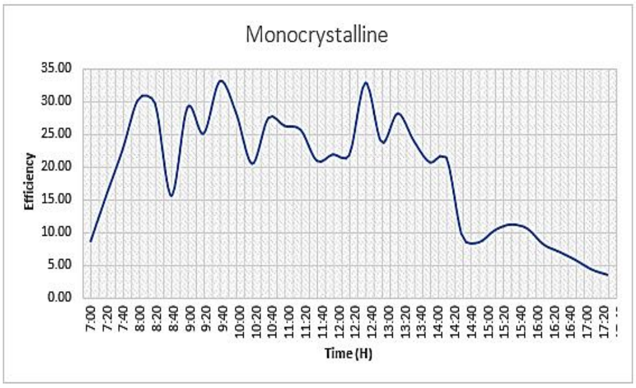
4.1 Presentation of Results



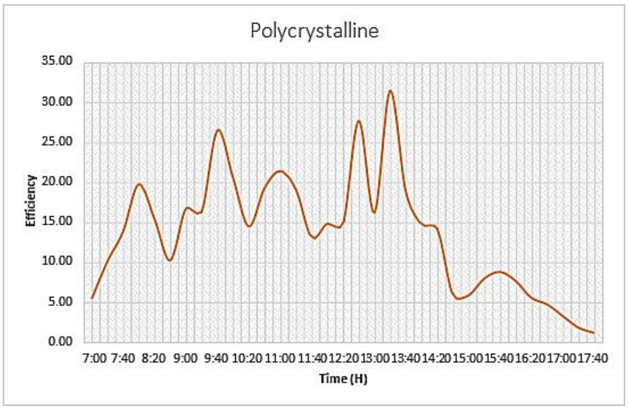
(a)

(b)

Figure 4.1 Graph of current against voltage generated by the two panels



(a)



(b)

Figure 4.2 The efficiency-time graph for the two panels

4.2 Discussion of Results

From the I-V graph, there is no linearity in the I-V curve which is due to the fluctuations of the sun's rays reaching the earth's crust due to change in atmospheric conditions. These fluctuations have profound effect on the performance of the panels. More so, the materials and technology by which the panels are produced also has remarkable consequences in the performance parameters of the panel.

Due to the nonlinearity of the I-V curve for solar panels, low energy conversion efficiencies are recorded and the fluctuations in the solar insolation and other factors gives a varying value for the efficiency during the experiment. It was also observed that between 10:20 am efficiency dropped but peaked about 11:00 am to 1:00 pm for both panels. As a result, the efficiency of the solar panels can be said to be optimal and almost always high during these periods. After these periods, the efficiency is seen to drop again as solar intensity reduces.

Generally from the figures, graphs and tables, it can be inferred that the power generated by the use of the monocrystalline solar panel is more stable. Conversely, the power generated by the polycrystalline solar panel is more erratic and characterized by poor efficiency values (see table 4.1).

Table 4.1 Performance parameters of the solar panels

SN	Parameter	Monocrystalline Panel	Polycrystalline Panel
1	Maximum voltage	15.12 (V)	13.11 (V)
2	Maximum current	2.87 (A)	1.92 (A)
3	Maximum Power	42.96 (W)	25.15 W
4	Maximum Efficiency	33.05%	31.44%
5	Minimum Efficiency	3.36%	1.13%
6	Average efficiency	19.07%	13.54%
7	Standard deviation of efficiency	7.9	5.9
8	Current at max. Power	2.87 (A)	1.92 (A)
9	Voltage at max. Power	14.97 (V)	13.10 (V)

4.3 Findings

According to the analyzed results, a comprehensive list of findings and deductions can now be made as follows:

1. Current/voltage (I-V) graph characteristics of a solar panel are not linear because of weather, temperature(sun intensity) and materials used.
2. From the tables, efficiency of a typical monocrystalline and polycrystalline solar panel is actually low compared with the rated power.
3. During cloudy cover, the solar panel does not produce enough power to charge batteries.
4. During cloudy weather conditions, the solar panel takes a longer time to charge the batteries.
5. During sunny weather condition, the solar panel charge faster and performs better.

V. CONCLUSION

The purpose of this study is to test the ability of the solar photovoltaic modules (solar panels) to convert the abundant energy available from the sun (solar energy) into usable electrical energy, and this has been determined as shown in the results.

There are several types of solar panels that exist; however, the common solar panels available in Nigeria, which are monocrystalline and polycrystalline solar panels, have been used in this study. The panels have been tested, and during the test, observations were made on some of the setbacks or drawbacks; the reason why the efficiencies of both solar panels are as low as obtained in the readings as well as in already established documentation. It is observed that the efficiencies are not enough for uninterrupted power supply, which is a major problem in Nigerian society. The maximum power for both monocrystalline and polycrystalline panels is 42.96 W and 25.15 W, respectively. To increase the efficiency, a separate device can be built to interphase between the solar panel and batteries; these devices can help boost the power that is tracked from the sun by the solar panel.

The low efficiency obtained reflects the irregularity of the sun's radiation during the day and the inability of the materials used in the production of the cells in the solar panels to efficiently convert available solar energy into useful electrical power. From the values obtained, monocrystalline and polycrystalline solar panels can produce electricity with an energy conversion efficiency similar to theoretically established values. The hallmark of this study was its ability to test the solar panels and observe that solar panels can convert solar (light) energy to electrical energy at a variety of conversion efficiencies that can be used in industrial and domestic applications such as powering electrical systems, charging batteries, etc. The peak time of the day when we get the most energy is at mid-day, which means that the solar panel functions more effectively. Our calculations indicate that mono-crystalline panels would be preferable to poly-crystalline ones for household use. Energy extraction is more economically sound and more long-term oriented.

REFERENCES

[1] H. A. Aribisala, "Improving the Efficiency of Solar Photovoltaic Power System," Ekpoma press, Benin, 2013.

[2] Kamanzi, J., & Kahn, M. T., "Development of a Model for Highly Efficient Solar Power," Suweto press, Israel, 2017.

[3] L. Jingcheng, "Application of solar energy. Ohio: Universal Energy Application Systems," Saimaa University of Applied Sciences, Ohio, 1959.

[4] Tyagi V., Rahim A., and Selvaraj A., "Progress in solar PV technology: Research and achievement," Renewable and Sustainable Energy Reviews, p. 443–461, 2013.

[5] M. A. Green, "Solar Cells; Operating Principles, Technology, and System Applications," In G. M. A., England: Prentice-Hall Inc, pp. (pp. xii, 62-184.), 1982.

[6] U. D. o. Energy, "Photovoltaic Cell Conversion Efficiency Basics," Department of Energy US, pp. 78-122, 2014.

[7] United Nation Report, "Renewable Energy Potential in Selected Countries Volume I," North Africa, Central Europe, and the Former Soviet Union and Volume II: Latin America Final Report, North Africa, Central Europe, and the Former Soviet Union and Volume II: Latin A, 2000.

[8] V. Smil, "21st Century Energy: Some Sobering Thoughts," OECD Obs: Available online: http://vaclavsmil.com/wp-content/uploads/docs/smil-article-2006-oecd-observer.pdf (accessed on 29 August 2019)., 2006.

[9] P. Jachquel, "Seven of the greatest solar stories over the millennia," Energyblog: https://energyblog.nationalgeographic.com/2013/09/23/seven-of-thegreatest-solarstories-over-the-millennia/,2017.

[10] B. Statistical, "Review of World Energy," BP Statistical Review of World Energy, 2019, 68th ed.: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019- full, 2019.

[11] R. Sanchez, "Solar panel," Wikipedia: www.wikipedia.com/solar-panel/, 1999.

[12] Tiwari G.N. and Dubey., "Fundamentals of Photovoltaic Modules and their Applications," Royal Society of Chemistry., Cambridge (UK), 2009.

[13] D. Thomas, "Materials Concepts for Solar Cells. (pp. 23- 38)," Imperial College Press, London (UK), 2014.

[14] &. J. a. J. Hefner, "The Grand Energy Transition: The Rise of Energy Gases, Sustainable Life and Growth, and The Next Great Economic Expansion.," Hoboken (USA): John Wiley and Son, USA, 2009.

[15] Ogwu. C. Daniel, Christopher Oseyi, and Ojo Idehen, , "Building and Performance Analysis of a Solar Panel.," Mechanical Engineering at the Faculty of Engineering, Ambrose Alli University, Ekpoma, 2020.

[16] K. Gordon, "How do photovoltaics work? In How do photovoltaics work (pp. 140-156).," Willey inter-science, New York, 2011.

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