A Computational Comparative Analysis of Solar Panel Performance under Outdoor and Indoor Environment

[1]Olamide O. Olusanya, [2]Olusogo J. Adetunji, [3]Charles D. Ajibola, [2]Ayobami T. Olusesi, [4]Bamidele M. Olukoya and [5]Olayinka A. Jongbo

[1]Department of Computer Engineering, Bells University of Technology, Ota, Ogun State, Nigeria
[2]Department of Computer Engineering, Olabisi Onabanjo University, Ago Iwoye, Nigeria
[3]Department of Electrical, Electronic and Telecommunication Engineering, Bells University of Technology, Ota, Ogun State, Nigeria
[4]Department of Computing and Information Science, Bamidele Olumilua University of Education, Science and Technology, Nigeria
[5]Department of Computer Science, Ekiti State University, Ado Ekiti, Nigeria
{ooolusanya| cdajibola}
@bellsuniversity.edu.ng|{adetunji.olusogo|olusesi.ayobami}|@oouagoiwoye.edu.ng|olukoya.musiliu@bouesti.edu.ng, olayinka.jongbo@eksu.edu.ng

Received: 21-MAY-2020; Reviewed: 19-JUNE-2024; Accepted: 20-JUNE-2024
https://dx.doi.org/10.4314/fuoyejet.v9i2.11
ORIGINAL RESEARCH

Abstract— The peculiar problem of unstable power supply in developing countries was a motivating factor for this research work. The problem of power supply is being resolved by renewable energy such as tidal, solar PV-based renewable energy, geothermal and solar renewable energy. The performance of three basic solar panel types kept in an indoor environment with an artificial light source and reflector was compared with the performance under outdoor environment. These solar PV types includes monocrystalline, polycrystalline, and silicon-amorphous which selected as a sample for the thin-film type of solar panel. Laboratory experiments were set up for these tests. PWM (pulse width modulation) concept of controlling AC was employed to achieve control for the enclosed indoor experiment. This was used to vary the intensity of the light bulbs placed inside the chamber built for the enclosed indoor environment. Reflectors were placed on the walls of the chamber to achieve better illumination within the chamber: thereby leading to better output efficiency from the panels being tested. From the obtained results, monocrystalline solar panel gave 25.45V, polycrystalline produced 26.68V and Silicon-amorphous gave 25.49V for the indoor experiment when the highest obtainable PWM voltage was 250V. The results obtained for the outdoor readings fluctuate because of the factors militating against PVs. The highest readings obtained for the panels were: 25.78V, 24.56V and 24.08V for monocrystalline, polycrystalline and silicon-amorphous respectively. From these obtained results, the deduction made was that monocrystalline PV has the highest output efficiency under outdoor environment while the polycrystalline PV has the highest efficiency under indoor environment. This paper worked on the comparative analysis of the results obtained for both indoor and outdoor environments.

Keywords— Monocrystalline, Polycrystalline, Silicon-amorphous, Solar Panel

1 INTRODUCTION

Renewable energy such as solar PV-based renewable energy, tidal and geothermal has the most affordable solutions to the problem of poor power supply (Williams *et al.,* 2019), most especially in developing countries such as South Sudan, Chad, Burundi, Nigeria, Malawi, Central African Republic, Burkina Faso, Niger and Liberia. Once the initial challenge of high implementation cost of renewable energy is overcome; there is little or no running cost for the sustainability of this power supply solution (Strielkowski *et al*., 2021). Despite this popularity and the advantages solar PV energy source has over other renewable energy; the fact that sunlight can only be available during the daytime alone has rendered this power solution incomplete (Shaikh, 2017).

Other environmental challenges such as deforestation, lethal material contamination, ozone layer degradation and global warming also pose difficulties to energy

*Corresponding Author

Section B- ELECTRICAL/COMPUTER ENGINEERING & COMPUTING SCIENCES
Can be cited as:
Olusanya O.O., Adetunji O.J., Ajibola C.D., Olusesi A.T., Olukoya B.M., and Jongbo O.A. (2024).
A Computational Comparative Analysis of Solar Panel Performance under Outdoor and Indoor Environment, FUOYE Journal of Engineering and Technology (FUOYE**JET), 9(2), 227-235.**
https://dx.doi.org/10.4314/fuoyejet.v9i2.11

Some potential approaches have been projected to lessen or evade the negative consequences of these environmental issues; such approaches include a decrease in the consumption include a decrease in the consumption of fossil fuel and support on the usage of environmentally sustainable energy sources (Ang *et al.*, 2022). Due to the potentials that solar cells have in power generation, they are one of these environmentally friendly energy sources which include: wind, tidal, geothermal etc. (Dincer & Meral, 2010). The captured energy is changed into direct current DC electricity by solar cell (Burke & Stephens, 2018). Semiconductors were used to make these solar cells. These semiconductors are materials that become electrically conductive when exposed to light or heat, but act as insulators in the dark and at low temperatures (Olabi & Abdelkareem, 2022). However, as useful as this information about solar panels can seem, a diversity of factors influence their performance and overall production quality in terms of efficiency (Mihai *et al*., 2019). Many environmental factors, such as dust, shadow and gloomy weather resulted into shortcomings of solar panels (Rashid *et al.*, 2023; Shaikh, 2017). The shadow of a dry tree cast on a solar panel, for example, can cause reduction in efficiency by up to 50%, as a result, it can be presumed that climate change has become a major source of worldwide concern due to its negative impact on global energy output, especially the development of alternative energy sources for non-renewable energy sources (Ang *et al*., 2022). Human actions are usually responsible for these changes in climate, according to the Intergovernmental Panel on Climate Change's fifth assessment report (Adetunji, Adeyanju, & Esan, 2023; Gaur & Tiwari, 2019; Julius *et al*., 2021; Olaniyan *et al*., 2023). It was claimed that fossil fuels are responsible for more than eighty percent of global total energy output (Das & Chowdhury, 2022). Global electricity produced directly as end products of non-renewable sources such as coal, petroleum products, etc. is estimated to be 9,168, 1,128, and 5,100 TWh (Ang *et al*., 2022). Burning of fossils give out greenhouse gaseous product like carbon dioxide and other gases as by-products and as a result, the concentration of these greenhouse gases is greatly amplified with each burning practice of these non-renewable, increasing the overall greenhouse effects (Olotu *et al*., 2018). Tidal energy, geothermal energy, solar energy, bio energy, and wind energy, are examples of renewable energy sources (Williams et al., 2019). Renewable energy's socioeconomic potential; in the report of World Energy Council scenarios, could conveniently supply twenty percent of globally consumed energy by the year 2030 and fifty percent by 2050 (Peng *et al*., 2020). Shadow, dust, and gloomy weather are examples of unfavorable environmental factors that have the tendency to reduce the specified expected performance of solar panels from the manufacturers (Adetunji, Adeyanju, Esan, et al., 2023; Chanchangi et al., 2022; Shaikh, 2017). This work focused on the performance of three different solar panels, namely monocrystalline, polycrystalline, and silicon-amorphous, under these environmental conditions in order to determine the delivered production efficiency in percentage and compare the obtained results with the obtained results from an enclosed indoor environment: Different studies have been conducted to examine the performance of photovoltaic systems in both outdoor and indoor settings, as well as how this affects their overall performance in terms of efficiency. However, the indoor comparison environment have often being open indoor settings, where the majority of the strength of light coming from the indoor is lost to the environment due to absorption. Also, the interference of the natural light with the artificial light renders the readings obtained at the end; unreliable. Furthermore, the net effect of this is a situation where the influence of this light emitted from the artificial light source is not as visible on the solar panel. This is why the indoor experiment was conducted in an enclosed chamber; with the addition of reflectors and high-intensity energy-saving bulbs, the light's effect on all of the solar PV(s) was important. As a result, the problem of absorption by the wooden surrounding environment within the chamber was completely eliminated. Different studies that have been carried out on the comparative analysis of solar PV performance, were basically based on the monocrystalline and polycrystalline solar panels (Mirzaei & Mohiabadi, 2017; Abubakar & Adamu, 2019). This study not only compared the performance of monocrystalline and polycrystalline solar PV as it has been done in other studies but also compared with Silicon-amorphous solar PVand specifically done in a new location (Sango Ota, Nigeria) where environmental factors differ.

2 REVIEWED RELATED WORKS

Socio- economic and environmental impacts of silicon-based photovoltaic (PV) technologies were examined by (Swapnil *et al*., 2016). This work focused on the global socioeconomic and environmental effects of silicon based photovoltaic PV technologies and realized that solar photovoltaic (PV) systems provide profound social and environmental based benefits over traditional energy sources which contributes to long-term growth. The emphasis was more on the solar panel manufacturing process and noted that the global spread of solar technology was based on slew of issues. One of the most prominent issues was that traditional PV (silicon-based) production methods have origins in the industries dealing in electronics, and lots of the chemicals used in e-waste, such as brominated flame retardants, lead, cadmium, and chromium, are also found in solar PV. Solar cells are manufactured with various poisonous, flammable, and explosive chemicals. It can be deduced from this that the technology can only be mastered by people who have a deep background in specific engineering fields. The study's work also included a reference point for the technology's hazardous effects. It was recently revealed, for example, that the disposal of electronic devices is gradually becoming an increasingly serious health and environmental issue in many countries. The impact of various climatic conditions on the overall performance of a solar panel in Romania was understudied by (Mihai *et al*., 2019). It was noted that PVs are suitable for residential and commercial buildings in areas with high levels of solar irradiation. This paper provides a case study of the impact of environmental factors on PV efficiency (i.e. atmospheric temperature, snow, and dust). Temperature measurements, infrared (IR) images captured with a Thermo vision camera, and visual inspections of PV make up the test. Over the course of a year, measurements were taken on the PV system. The heat dissipation in a PV module was mapped in infrared. (Gaur & Tiwari, 2019) worked on the performance of photovoltaic modules of various solar cells. The performance of semi-transparent and opaque (PV) modules of various generations of solar cells was examined. In the case of a commercially accessible semi-transparent and opaque PV module, the outdoor output of each solar cell type was also evaluated. Yearly electrical energy, capitalized cost, annualized uniform cost (unicast), and cost per unit electrical energy for both semi-transparent and opaque solar modules, as well as their characteristic curves, must be computed, according to the report. If semi-transparent PV modules outperform opaque PV modules in terms of performance. Calculation reveal that for laboratory made PV modules, CdTe has the highest annual electrical energy generation and the lowest cost per unit of electrical energy, while for commercially available solar modules; a-Si/nc-Si has the highest yearly electrical energy generation and the lowest charge per unit of electrical energy. Over all other PV technologies, CIGS has the lowest capitalized expense. (Rashid *et al.,* 2023) Examined factors influencing the performance of solar panels. The study stressed that the form of solar PV defines its efficiency under various factors. Such factors are solar irradiation, shade and mounting location. (Manickam *et al*., 2023) found that not all solar PVs are produced equal, even though they have the same power rating and other features inscription from the manufacturer, in a study titled: 4 factors that can upset solar PV production: Solar panels are distinguished by their efficiency ratings, power ratings, and degradation rates. It was made clear that: orientation, latitude, tilt, and climate do have significant influences on a solar PV system's performance, so if plan is made to offset one's electric bill with solar PV, it is imperative to know how these factors can influence solar production. The Effect of Solar Panel Tilt on Solar PV Production: The tilt of solar PVs can have a significant impact on system's general performance. Since the sun is higher all through the summer and lower throughout the winter, one can change the tilt of solar panels throughout the year. However, since they have moving parts, systems monitoring the sun are more costly and need maintenance. Every fixed-tilt system has an optimum angle at which it will get the most out of each period, and while limited degrees might not seem like much in one year, the difference over the system's lifespan may be important. Solar Panel Production is affected by Latitude: Latitude has a significant result on solar system manufacturing. Owing to the tilt of the planet as it turns on its axis, systems located at higher latitudes can produce lesser output statistics during the year. In order to offset their payment, a homeowner in the north-eastern United States would need a larger system than a homeowner in the southwest. There isn't anything you can do to change your system's efficiency when it involves latitude unless one is willing to move, so plan for reduced production and scale accordingly. Climate Change Has an Effect on Solar PV Production: Climate change can have a significant impact on a system's efficiency. In cold environments, for example, there is a popular assumption that modules can generate less. The inverse is real. Heat is the adversary of efficiency, and cold conditions can prevent solar panels from high temperature and losing efficiency. Snow is also reflective, concentrating sunlight and increasing total irradiance. (Ay *et al*., 2016) Performed power case study for both monocrystalline solar PV and polycrystalline solar PVs which was carried out at Bursa City, Turkey. The work showed how time-dependent power generation under diverse loads varies under two different solar PVs under Bursa province conditions between August 19 and 25, 2014. Solar panels, pyrheliometer, inverter, pyranometer, multimeter, accumulator, temperature sensor, regulator, and data-logger are among the testing sets. Based on the measurements of climatic data, the efficiency of polycrystalline and monocrystalline solar PVs was determined the average output of monocrystalline and polycrystalline sheets, according to the report, is 42.06 Wh and 39.80 W, respectively. Under absolute overall radiation (1001.13 W/m2), 87.14 W instantaneous power was gotten from the monocrystalline solar panel and 80.17 W instantaneous power was obtained from the polycrystalline solar panel. Within this time limit, it was discovered that monocrystalline solar PVs are more effective than polycrystalline solar panels in Bursa's conditions. When the multivariate correlation coefficients were statistically tested, it was discovered that there was a strong positive relationship between total and direct radiation, as well as ambient temperature, on energy production from monocrystalline and polycrystalline plates. (Mokari & Heidarzadeh, 2023) Carried out research on efficiency enhancement of an ultra-Thin Silicon Solar Cell Using plasmonic Coupled Core-Shell Nanoparticle. The study focused on the potential features that a solar panel might have and used within the active layer of a thin-film silicon solar cell to enhance absorption and thus photocurrent. The focal goal is to create a high-efficiency solar cell with two or three coupled nanoparticles embedded. The proposed structures are simulated using the finite-difference time-domain (FDTD) method. The location, distance, and radius of nanoparticles are all optimized. The effects of embedded coupled nanoparticles are contrasted with a single embedded nanoparticle event. The results showed that coupled nanoparticles increase cell efficiency considerably. For example, the optical current in a cell with two coupled nanoparticles is 33.53 m A/cm2, while in a cell with three embedded coupled nanoparticles it is 34.49 m A/cm2. It's worth noting that the optical currents for cells with one nanoparticle and cells without nanoparticles are 31.74 m A/cm2 and 20.11 mA/cm2, respectively. Finally, a titanium oxide core with various radiuses within silver nanoparticles is considered to improve things even further. Titanium oxide cores improve optical absorption and photocurrent by reducing absorption within the metal. (Urbina *et al*., 2022) Adopted roll-to-roll methods under ambient conditions for a life cycle analysis of polymer solar cell modules. The ITO film was etched, stripped, washed, and dried using a complete roll-to-roll process, which included screen printing an etch resist and then applying etching, stripping, washing, and drying procedures. The silverback electrode was screen printed after the three subsequent layers, ZnO, P3HT: PCBM, and PEDOT: PSS, were slot-die coated. Finally, a polyester barrier material was used to encapsulate the polymer solar modules. Except for the application of ITO, all operations were carried out in natural light The life cycle analysis included a material inventory of the entire module manufacturing process as well as transparency for the energy embedded in both the raw materials and the manufacturing processes. Calculation of energy pay-back time based on power conversion efficiencies and module lifetime allowed us to relate roll-to-roll manufacturing with other organic and hybrid photovoltaic technologies. According to the findings, an organic solar module with a 2 percent efficiency will achieve an Energy Pay-Back Time (EPBT) of 2.02 years, which can be lessened to 1.35 years duration if the efficiency is increased to 3 percent. The main goal of Hamid Heidarzadeh's work, Incident light management in a thin silicon solar cell utilizing a two-dimensional grating Gaussian distribution, was to look into the efficiency requirement of a thin silicon solar cell on non-uniformity in the size of the rectangle back gratings. A rectangular back grating with a Gaussian random distribution is used to improve performance. One of the most popular optical trapping techniques is the grating. To upturn the light traveling length within the active zone, a rectangular grating is positioned at the back as a mirror that reflects and scatters light into the absorber. DBR and horizontal grating are used in the rear side and we focus on the non-uniformity of rectangle grating sizes to govern the light inside the cell. The results show that absorption spectra can be efficiently controlled and the photocurrent can be substantially increased using this structure. The efficiency of a 3m Si-type solar cell has been increased by nearly 20%. Furthermore, the efficiency of the proposed structure is higher than average incidence when the angle of incidence is about 5 to 20°. The findings are thought to be useful in the development of a thin-film silicon solar cell. The conclusion that can be drawn from all of the reviewed works is that none of them have previously focused on any study of solar panel efficiency in a closed indoor environment with no external influences. All in the indoor chamber is managed and governed in the way that you want it to be. Shade, a dusty atmosphere, a gloomy environment, and other factors have no impact on the planned production quality. Abubakar & Adamu (2019) compared the performance of monocrystalline and polycrystalline under certain environmental factors in Kebbi State. The results showed that monocrystalline solar PV has a better performance than polycrystalline Also Mirzaei & Mohiabadi (2017) examined similar work in semi-arid area in Iran. Monocrystalline modules performed better with overall efficiency and energy yield.

3 MATERIALS AND METHOD

Different stages were taken to evaluate the comparative analysis of solar panel performance under outdoor environment and enclosed indoor environment. Those steps are concurrent data collection under outdoor and indoor environments, sorting of the collected data for analysis purpose, analysis of the sorted data, performance evaluation of the analysed data and modeling of PV performance characteristics. This study was carried out in Ota. Ota (also written Ota') is a town in Ogun State, Nigeria, with an estimated population of 163,783 people living in or around it. The Ado-Odo /Ota Local Government Area's capital is Ota. Sango Ota is its original name (with diacritics), and its geographical coordinates are 6° 42' 0" north, 3° 14' 0" east. (2015, Oshinowo) As previously mentioned, it is a town in Nigeria, which is a country situated between 4° and 14° north latitude. Throughout the year, the nation receives a large amount of solar energy. This is why Ota has a plentiful supply of energy. This energy could be put to good use in the construction of solar power systems. Solar radiation data, in various forms, is needed for this reason, depending on the type of application. Ota has a solar irradiance value that varies depending on the time of day and weather at that particular time, according to the simulation done with PVSYST software. The solar PV cell output current was determined using the following equations

$$I = I_L - I_D - I_{sh} \qquad \text{A(10)}$$

(10)

$$I_d = I_0\left(\exp\left(\frac{V+IR_E}{N_{id}V_t}\right)\right) \qquad \text{i}$$

$$V_t = \frac{KT_c}{q} \qquad \text{ii}$$

$$I_{sh} = \left(\frac{V+IR_s}{R_{sh}}\right) \qquad \text{iii}$$

Substituting Equations. (i), (ii) and (ii) into Equation. (A), the output current of the solarcell is then represented by Eq. (B):

$$I = I_1 - I_0\left(\exp\left(\frac{V+IR_E}{N_{id}V_t}\right) - 1\right) - \left(\frac{V+IR_S}{R_{sh}}\right) \qquad \text{B}$$

Where I is the output current of the Solar Cell
I_L is the photo or solar-generated current
I_D is the diode current
I_{sh} is the shunt- leakage current
I_0 is the diode reverse saturation current
N_{id} is the ideality factor
V_t is the thermal voltage (V)
T_C is the absolute temperature
R_S is the series resistance
R_{sh} is the shunt resistance

3.1 MATERIALS USED

Two monocrystalline solar PV, two polycrystalline solar PV, and two silicon-amorphous were used. For this study, six solar PV modules of peak power equals to 100 Watts of each module that was used, the data for each of the three types of panels used are shown in Tables 1and 2. For, the monocrystalline module, there are thirty-three solar cells on each of the modules. Each of these cells is of dimension 16 × 16 cm². Six batteries of 7.2AH, 12V were used to determine the charging rate of the solar panels. No charge controller was used with the solar panels to prevent any form of interference with the readings taking at every interval; of measurement taking. Three digital meters, three analog meters, PWM (pulse width modulator) inverter, the enclosed indoor panel chamber embedded with light reflectors.

3.2 CONCURRENT DATA COLLECTION UNDER OUTDOOR AND INDOOR ENVIRONMENT

The data collection was done by setting up two different solar harvesters; a set for the outdoor measurement and the other one for the enclosed indoor measurement. For the outdoor measurement, the readings were taken at an interval as shown in Tables 3and 4. A total of 24 days were used for this outdoor data collection process. Measurement for each panel was done daily for 4-hour interval duration. The connection for the panels for data capturing was done for each of the panels as shown in Figures 2 and 3. The captured readings are tabulated in Table 3 and 4. The indoor data collection was done at an interval as well. To set up the indoor solar harvester, the PWM variable AC generator was built around the SG3524 oscillator. The unit built can give an AC output between 0-280V. The frequency for the pulse width modulation was set at 50HZ for it to operate at the same frequency the connected load is expected to operate. The designed indoor solar PV chamber was built with wood and it has a dimension of 154cm x 60cm x 40cm. The inner walls of this wooden chamber were covered with reflectors to increase the intensity of the light bulbs that are placed inside the chamber. This chamber was provided with a cover to prevent external influence from outer light sources. The solar PV to be used for testing purposes was always placed at the bottom of this chamber. The terminals of the solar PV were led out for connection to the load (battery) to be charged. The terminals of the seven bulbs are connected to form a single link, and the common terminals are fed out to provide a source of connection to the output of the PWM AC generator. The cover of the chamber was thereafter closed to take the required readings. The voltmeter is connected in parallel with the terminals of the connected load (battery to be charged). The solar panel under test is connected in such a way that its positive terminal is connected to the battery via an ammeter (series connection). Each panel under test is tested with five sets of PWM voltage selected randomly. The solar panel is made to charge the connected battery for 30 minutes.

Table 1: Electrical Materials Measurement

Description	**Quantity**	**Specification**
Microcontroller	2	PIC16F877A
PWM IC	2	SG3524
BILATERA SW IC	2	CD4066BP
Monocrystalline	1	100W
Polycrystalline PV	1	100W
Silicon Amorphous PV	1	100W
Crystal Oscillator	1	16 Mhz
Regulator	2	LM317
Soldering Lead	1	Alloy (Roll)
Casing Unit	1	30 X 180cm^2
Reflector	1	30 X 189 cm^2
Transistor	6	BD139
IC Socket	2	20 X 20

Table 2: Module Characteristics of the Used Panels

Monocrystalline

Peak power (Wp) *V*	OC (V) *I*	SC (A) *V*	MP (V) *I*	MP (A)	*η*(%)	Area (m^2)
100	22.8	6.4	17.6	5.71	17.46	0.575

Polycrystalline

Peak power (Wp) *V*	**OC (V) *I***	**SC (A) *V***	**MP (V) *I***	**MP (A)**	***η*(%)**	**Area (m^2)**
100	22.3	6.4	16.8	5.24	15.72	0.575

Silicon-Amorphous

Peak power (Wp) *V*	OC (V) *I*	SC (A) *V*	MP (V) *I*	MP (A)	*η*(%)	Area(m^2)
100	24	6.4	15.6	5.16	13.38	0.575

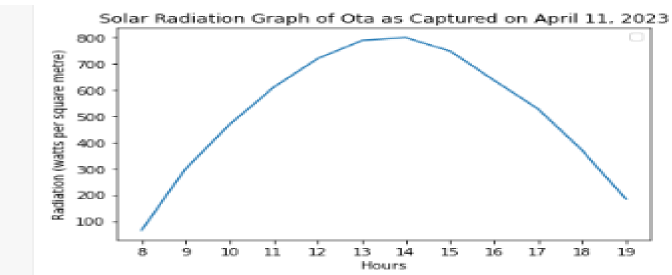

Figure 1: Solar Radiation of Ota as captured on April 11, 2023

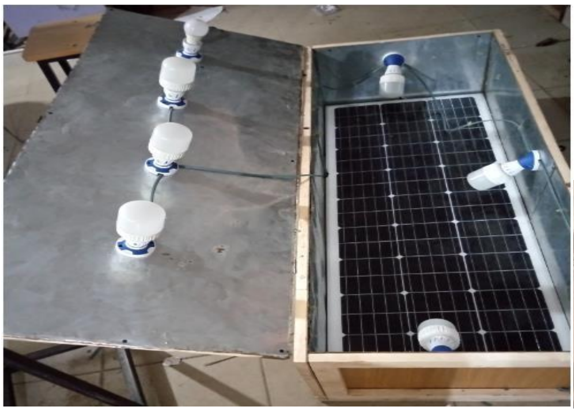

Figure 2: Set up experiment for the Indoor Readings

Figure 3: Set up experiment for the outdoor Readings

Table 3: Results (Average) obtained from the Solar Panel Performance under Indoor Environment

S/N	PWM VOLT (V)	MONOCRYSTALLINE VOLT (V)	POLYCRYSTALLINE VOLT (V)	SILICON-AMORPHOUS VOLT (V)
1	70	12.66	12.76	12.67
2	80	12.71	13.14	13.01
3	90	12.90	13.76	12.44
4	100	13.22	13.78	13.47
5	120	13.74	14.68	13.94
6	135	14.45	14.72	14.66
7	150	15.09	15.22	15.12
8	160	15.23	15.86	15.64
9	165	15.60	16.09	15.92
10	170	16.46	17.12	16.92
11	180	17.56	21.52	18.54
12	185	18.36	20.56	19.66
13	190	18.56	20.66	19.72
14	195	19.89	20.76	20.46
15	200	19.96	23.12	20.76
16	210	20.26	23.16	21.96
17	215	21.32	23.64	22.56
18	220	21.56	24.76	22.86
19	225	22.96	24.56	23.45
20	230	23.22	25.02	23.56
21	235	24.00	25.75	24.65
22	240	24.29	25.95	24.95
23	245	25.00	26.20	25.40
24	250	25.45	26.68	25.49

Table 4: Results (Average) obtained from the solar panel performance under outdoor environment

S/N	PWM (V)	MONOCRYSTALLINE (V)	POLYCRYSTALLINE(V)	SILICON-AMORPHOUS (V)
1	70	12.46	12.02	10.66
2	80	13.14	12.44	10.71
3	90	13.76	12.46	11.20
4	100	13.78	13.22	11.47
5	120	14.68	13.44	11.74
6	135	14.72	13.45	11.76
7	150	15.02	13.65	11.78

8	160	15.22	13.72	11.86
9	165	15.34	13.96	12.04
10	170	15.35	14.92	14.46
11	180	16.52	15.54	15.36
12	185	17.56	16.66	16.06
13	190	18.66	17.32	16.56
14	195	19.76	18.46	17.96
15	200	20.12	19.76	19.19
16	210	20.16	19.96	19.26
17	215	20.64	20.56	19.32
18	220	21.76	20.70	19.56
19	225	22.86	21.56	20.96
20	230	23.01	22.76	22.03
21	235	24.45	23.67	22.30
22	240	24.78	23.79	23.03
23	245	24.98	24.46	23.48
24	250	25.78	24.56	24.08

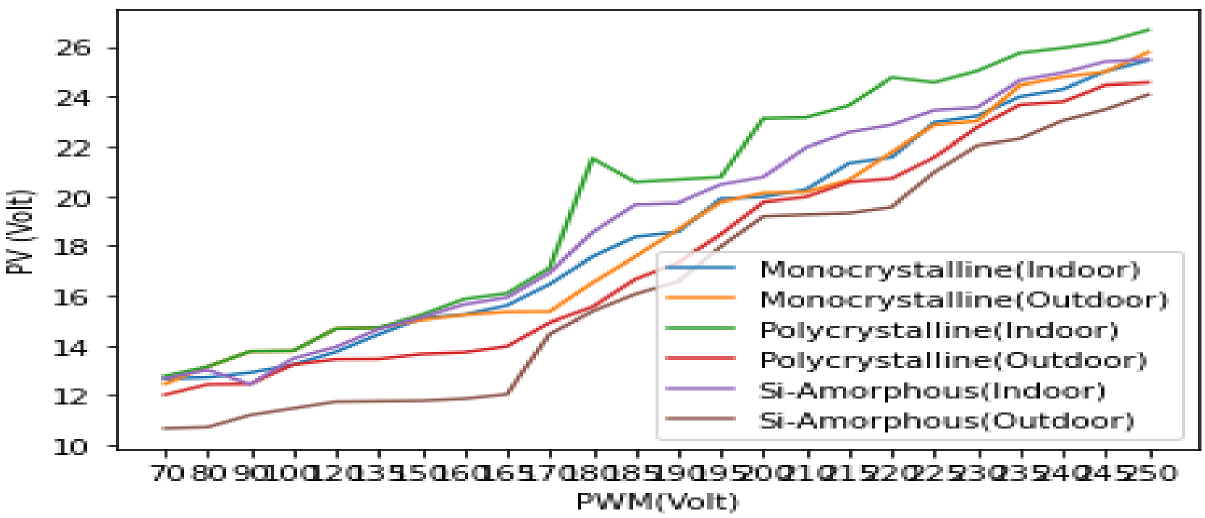

Fig. 4: Comparison of Solar Panel Performance for both Indoor and Outdoor Environments

4 RESULTS AND DISCUSSION

Two different sets of results were obtained from the experiments performed for both the outdoor and indoor environments. For both indoor and outdoor environments, the readings were taken consecutively for twenty four days. The diagram for the connection of both Indoor and outdoor environments are shown in Fig. 2 and 3. The connection was done without any charge controller: so that the solar panels' readings will not be influenced in any way. The readings were taken at an interval of 4 hours for twelve hours. The obtained readings are as tabulated in Tables 3 and 4. The indoor readings were taken in four different intervals: with the taken readings for each interval of six. These readings are represented and compared diagrammatically with Fig. 4. The results obtained reflect that monocrystalline solar panels still gives out the best output in terms of output efficiency. Closely followed by polycrystalline solar PV and finally, the silicon- Amorphous solar PV. The effect of cloudy weather was noticed in all the solar panels as there were reductions in the obtained results for all the solar panels. This can be seen clearly in the graphs showing individual performances of the solar panels. The effect of the cloudy weather was more pronounced on monocrystalline and polycrystalline solar PV. From the chart representation of the indoor performance shown in figure 4. It was observed that the responses of all the solar panels are not fully directly proportional to the signal from the PWM. There seems to be little or no response from the panels for voltage between 70V and 150V. The response after this appeared to be directly proportional to the PWM AC signal after this. This means that the intensity of light after 150V is more pronounced on the solar panels. This graph in figure 4 showed that under the enclosed indoor performance, polycrystalline solar PV has the best performance characteristics. This implies that when there is no influence from the external environment, polycrystalline has better performances than the other two panels. Comparing the results obtained with other literatures, both Abubakar & Adamu (2019) and Mirzaei & Mohiabadi (2017) both discovered that the performance of the monocrystalline in terms of efficiency and energy yield under outdoor environment in the two different study areas better than the polycrystalline modules. This study discovered that monocrystalline solar PV perform better under outdoor environment than polycrystalline solar PV but vice versa for the indoor environment.

5 CONCLUSION

Research on solar photovoltaic (PV) is continuous , hence this work is a typical pointer that each of the solar panels made can deliver more output than what is even specified by the manufacturer and thereby making it possible for a solar panel to have higher efficiency. The behavior of the panel under a low PWM AC signal is also a pointer in another direction as the increase in the intensity of light falling on the surface ofthe panel appeared to produce little or no effect in terms of output voltage. This requires further research to establish what factors are responsible for this. The sudden increments that occurred after this state where no change seemed to occur wasanother major observation. The implication of this is that the I-V characteristic curve of diode used for solar PV modeling may be subjected to debate. The impact of temperature on solar PVs (especially in the indoor environment) was not verified in this research work. Further research may still spell out the effect this may have on all the used solar panels'output efficiency.

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