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THE EFFECT OF RELATIVE HUMIDITY ON OUTPUT PERFORMANCE OF INCLINED AND AUTOMATIC TRACKING SOLAR POWER SYSTEM.

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ABSTRACT

The effect of relative humidity on the output performance of a solar power system using 70 Watts Multi-Silicon and 80 Watts Mono-Silicon Solar Modules that were set up independently in Port Harcourt (latitude 4^0 55' 58" North and longitude 6^0 59' 55" East), Rivers State, Nigeria (tropical climate region) was studied during the month of October and November in University of Port Harcourt environs. The set-up of 70 Watts solar panel was inclined stationary at 15^0 for maximum solar reception while the set-up of 80 Watts solar panel had automatic solar tracker for effective capturing of solar radiation. For 70 Watts solar panel, the maximum power output of 59.99 Watt was obtained when the relative humidity was 30%. The minimum power of 0.00 watt was recorded when the relative humidity was 92%. There was 14.3% loss from maximum power output produced by 70 Watts solar module when compared with solar panel manufacturer's power rating. For 80 Watts solar panel, the maximum output of 77.20 Watts was recorded when the relative humidity was 41% while minimum power output of 0.00 watts was recorded when the relative humidity was 100%. The percentage loss in power output of 80 Watts solar module was 3.5% when compared with the solar module manufacturer's power rating. The results in both cases show inverse proportionality between solar panel's power output and relative humidity. In addition, the use of automatic solar tracker effectively improved the efficiency of the solar power system in the environment (i.e. from 14.3% loss to 3.5% loss). Specifically, the efficiency of the power output of solar module in this environment was improved by approximately 11% when solar tracker was installed with solar power system.

INTRODUCTION

From ancient times to present, the sun has been used to power many systems such as solar water heater, solar dryer and solar refrigerator. Extracting useable electricity from the sun was made possible by the discovery of the photoelectric mechanism and subsequent development of the solar cell (Green, 2002).

Solar Power is the energy that has been released by the sun in sunlight, controlled by one of several methods and converted into useable thermal or electrical energy. In other words, solar energy is the utilization of the heat and light radiated from the sun using solar technologies.

Solar cell is the unit that captures energy embedded in the solar radiation (photons) and converts it to electricity. The combinations of interconnected solar cells make up the solar module. Also, further combinations of solar modules are the solar panel.

Muneer et al, 2005 defined Photovoltaic cell as a device that converts sunlight to electricity. A photovoltaic (PV) cell, also known as solar cell, is a semiconductor device that generates electricity when exposed to light. When light strikes a PV cell, the photons dislodge the electrons from the atoms of the cell and the free electrons then move through the cell, creating and filling holes in the cell. This movement of electrons and holes generates electricity. The physical process by which a PV cell converts light into electricity is known as the photovoltaic effect.

Benerjee, 2010 disclosed that sun is the largest and richest energy source available to human kind. The sunlight that powers solar cells travels through space at 186,282 miles per hour to reach the earth 8.4minutes after leaving the surface of the sun.

Despite the distance at which the earth's orbits the sun (150 million kilometres), the sun provides an unfailing supply of radiant energy in order of 15,000 times the primary energy requirement of the entire population of the earth (www.google.com/gwt/x?client=ms-aff-mBrowser&U) assessed on 13th March, 2014.

Solar energy is among other renewable sources of energy and it is classified as a direct form of energy. Others are biomass, geothermal, tidal and wind.

On a global basis, the total radiant energy available at the sun's surface is of the order of 751 x 10^{15} Km hr/year (Priest, 1975). But as the energy propagates out, it spreads and become less concentrated. Some estimate put it that the incident radiation reaching the earth's surface amounts to 172 x 10^{9} MW. On an area of one square meter ($1m^2$) oriented at right angles to incoming sunlight, the flow of solar energy that arrives at the earth outside the atmosphere (the solar constant) is about 1.353kW. This radiant energy changes due to change in distance from the earth to the sun during the year, atmospheric conditions, angle of incident of the sun's ray e.t.c.

Solar energy is advantageous because it is noiseless, clean source, pollution free and relatively no cost of maintenance since no mechanical moving parts are involved in its installation.

Green (2002) found out that the average solar radiation potential for tropical climate region is about 16.4 ± 1.2MJ/m^2 per day. With this amount of solar radiation, solar energy is therefore considered as a potential energy source for domestic, industrial and commercial buildings.

A solar tracker is a device designed to trace or follow the direction of movement of sun for optimum reception of solar radiation. It is usually employed so that PV cell can capture maximum solar radiation.

A solar tracker is a device for orienting a solar photovoltaic panel or concentrating solar reflection towards the sun for maximum reception of solar radiation. There are many types of solar trackers of varying costs, sophistication and performance. The sun tracker could boost the collected energy 10 - 100% in different periods of time and geographical conditions.

It is found that the power consumption by tracking device is about 2 – 3% of the increased energy (Mousazadah et al, 2009).

Scientia Africana, Vol. 13 (No.1), June 2014. Pp 9-23
 ISSN 1118 - 1931

There are many different types of solar tracker which can be grouped into single axis and double axis models. Single axis solar tracker (Figure 1) can either have a horizontal or vertical axis. The horizontal type is used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes (such as UK) where the sun does not get very high, but summer days can be very long. These have manually adjustable tilt angle of 0-45^0 and automatic tracking of the sun from the east to west. They use PV modules as light sensor to avoid unnecessary tracking movement and for reliability. At night, the trackers take up a horizontal position.

Double axis solar trackers (Figure 2) have both a horizontal and vertical axle and so can track the sun's apparent motion exactly anywhere in the world. This type of system is used to control astronomical telescopes, and so there is plenty of software available to automatically predict and track the motion of the sun across the sky. Dual axis trackers track the sun both east to west and north to south for added power output (approximately 40% gain) and convenience.

Figure 1: Typical Single axis tracker.

Figure 2: Typical Dual-axis tracker

Ashok and Dutta (1990) designed a versatile microprocessor based controller for solar tracking system. The controller had the capability of acquiring photovoltaic and metrological data from a photovoltaic system and controlled the battery/load. These features were useful in autonomous PV system that was installed for system control as well as monitoring. In remote areas, solar tracking was achieved in both open loop as well as closed loop models. The controller was very automatic and did not require any operator's interference unless needed by the operator.

Konar and Mandal (1991) designed a microprocessor based automatic position control scheme. The design controlled the azimuth angle of an optimally tilted photovoltaic flat type solar panel or a cylindrical parabolic reflector to get the illuminating surface appropriately positioned for the collection of maximum solar irradiance.

Zeroual et al, (1997) designed an automatic sun tracker system for optimum solar energy collection. Electro-optical sensor was employed for sun finding and microprocessor controller unit for data processing and for control of mechanical drive system. The system follows the sun position and tracks the solar energy for optimum efficiency.

Hunang (1998) designed a micro controller based automatic sun tracker combined with a new solar energy conversion unit. The automatic sun tracker was implemented with DC motor and a DC motor controller.

Hassan (1998) designed and implemented a fuzzy logic computer controller sun tracking system to enhance the power output of photovoltaic solar panels. The tracking system was driven by two permanent magnet DC motors to provide motion of the PV panels in two axes.

Olusegun et al (1980) explained that the average temperature distribution throughout the year in hot wet climatic regions is about 28 ± 1^0C while the relative humidity in the morning is about 80% and above.

Green (1956) declared that all aspects of the earth's climatic indices such as wind, rain, clouds and temperature are the results of energy transfers and transformations within the earth. The seasoned variation of the solar radiation and how the axis of the earth is tilted to the plane of its angle at which the solar radiation strikes the earth's surface varies from season to season (Frohlish and London, 1985)

Humidity is a term used to describe the water vapour content in the atmosphere. Atmospheric water vapour originates from the earth's surface by evaporation and transpiration. It is therefore strongly concentrated in the lower layers of the atmosphere. There is usually a steady decrease in the moisture content of the atmosphere with increasing height. Beyond the tropopause, water is virtually absent (Ayoade, 2004).

Absolute humidity is the total mass of water in a given volume of air and Relative humidity is the ratio of actual moisture content of a sample air to that same volume of air can hold at the same saturated temperature and pressure.

Akinnubi et al (2007) stated that the relative humidity (RH) expresses the degree of saturation of air as a ratio of the actual vapour pressure to the saturation vapour pressure at the same temperature.

It is important to bear in mind that the relative humidity does not really give information about the quantity of moisture in the atmosphere but how close to saturation the air is; it is found that the lower the relative humidity of the air, the greater is the capacity of the air to absorb more moisture (Keith, 2003).

Mathematically, $RH = \frac{100\rho_a}{\rho_0 T}$ (1)

where :
ρ_a is the actual vapour pressure in kPa
ρ_0 is the saturation vapour pressure in kPa
T is the temperature in Kelvin.

The aim of this study is to determine and compare the effect of relative humidity on the efficiency of inclined and automatic tracking solar cells in the geographical location.

MATERIALS AND METHODS

The solar power systems comprise of 70 Watts Multi-Silicon Solar cells, 80 Watts

Scientia Africana, Vol. 13 (No.1), June 2014. Pp 9-23
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mono-silicon Solar cells, Automatic Pole tracker (locally constructed), 100Ah Prostar battery and a 0.5kVA inverter. The Automatic and Manual Pole trackers were set-up at an open field of University of Port-Harcourt, Nigeria (4^0N 6^0E). The 70Watts solar panel was then placed on the adjustable pole tracker of about 5metres high facing the sun and at an elevation of 15^0. The 80 watts solar panel was installed with automatic solar tracker (Figure 3) independently. The setups were arranged in the month of October and November. The bolts of the protector of the trackers were then tightened to the tracker to prevent the solar panel from falling off the fabrication. The output terminals of the solar panel were connected to the input terminals of the inverter. The open-circuit voltage and the short-circuit current were measured from the solar panel output terminals using digital multimeter at 15 minutes interval from 7.30 a. m. to 6.30 p. m. when the short-circuit current gives zero output. Sequentially, analogue hygrometer (Figure 4) attached to the set-up was used to measure relative humidity of the environment at 15 minutes interval.

Figure 3: The employed locally constructed dual-axis solar tracker in-situ.

Figure 4: The employed analogue hygrometer

The power output of the set-up is expressed as:

$$P_{out} = V_{oc} \times I_{sc} \quad (2)$$

where :

P_{out} is output power in watts

V_{oc} is the open-circuit voltage in Volts.

I_{sc} is the short-circuit current in Amperes.

The efficiency is generally expressed as:

$$Efficiency = \frac{PowerOutput}{PowerInput} x100\% \quad (3)$$

RESULTS

Table 1 shows the typical data collected on day 1 from 70 watts manually inclined solar panel. Table 2 shows the typical daily average readings for relative humidity, short-circuit current, open-circuit voltage, power and efficiency achieved from 70 watts manually inclined solar panel during the period of measurements.

Table 1: The data collected on day 1 (70 watts solar panel)

Time	Relative Humidity (%)	I_{sc}	V_{oc}	Vac	Power (watt)	Efficiency (%)	Weather Remarks
7.30am	94	0.03	18.62	210	0.56	0.8	No Sunshine
7.45am	95	0.06	18.94	208	1.14	1.63	No Sunshine
8.00am	93	0.20	19.44	210	3.89	5.56	Sunrise/low intensity
8.15am	85	0.48	19.24	214	9.24	13.20	Low sunshine intensity
8.30am	89	0.99	19.44	212	19.25	27.50	Low sunshine intensity
8.45am	83	0.98	19.94	214	19.54	29.91	Low sunshine intensity
9.00am	70	0.71	19.96	215	14.17	20.24	Moderate sunshine
9.15am	71	1.32	19.96	215	26.35	37.64	Moderate sunshine
9.30am	75	1.28	19.42	214	24.86	35.51	Moderate sunshine
9.45am	70	0.76	19.04	212	14.47	20.67	Moderate sunshine
10.00am	63	1.49	19.58	215	29.17	41.67	Moderate sunshine
10.15am	55	1.70	20.00	210	14.00	20.00	High sunshine
10.30am	59	0.82	19.38	211	15.89	22.70	High sunshine
10.45am	73	0.94	19.58	221	18.41	26.30	Moderate sunshine
11.00am	64	1.74	19.67	220	34.23	48.90	High sunshine
11.15am	52	2.06	19.58	221	40.33	57.61	High sunshine
11.30am	54	1.98	19.44	218	38.49	54.99	High sunshine
11.45am	54	1.84	19.22	213	35.36	50.51	High sunshine
12.00pm	53	2.04	19.32	215	39.41	56.30	High sunshine
12.15pm	49	2.08	19.98	224	41.56	59.37	High sunshine
12.30pm	50	2.22	19.91	215	44.20	63.14	High sunshine
12.45pm	56	0.80	18.46	215	14.77	21.10	High sunshine
1.00pm	56	1.99	19.85	215	39.50	56.43	High sunshine
1.15pm	45	2.15	19.91	217	42.81	61.16	High sunshine
1.30pm	45	1.54	19.53	216	30.08	42.97	High sunshine
1.45pm	48	1.98	19.92	217	39.44	56.34	High sunshine
2.00pm	50	1.50	19.02	214	28.53	40.76	High sunshine
2.15pm	48	1.49	19.83	215	29.54	42.21	High sunshine
2.30pm	49	1.65	19.97	214	32.95	47.07	High sunshine
2.45pm	46	1.50	19.90	216	29.85	42.64	High sunshine
3.00pm	45	1.60	19.86	217	31.78	45.40	High sunshine
3.15pm	49	1.51	19.92	219	30.08	42.97	High sunshine
3.30pm	53	1.23	19.84	219	24.40	44.86	High sunshine
3.45pm	54	1.13	19.77	218	22.34	31.91	High sunshine
4.00pm	60	0.75	19.61	216	14.71	21.01	High sunshine
4.15pm	61	0.80	19.72	219	15.78	22.54	High sunshine
4.30pm	61	0.70	19.60	222	13.72	19.60	High sunshine
4.45pm	65	0.64	19.60	224	12.54	17.91	Moderate sunshine
5.00pm	66	0.41	19.22	223	7.88	11.26	Moderate sunshine
5.15pm	70	0.34	19.12	220	6.50	9.29	Moderate sunshine
5.30pm	71	0.24	18.79	221	4.51	6.44	Moderate sunshine
5.45pm	75	0.13	18.15	217	2.36	3.37	Moderate sunshine
6.00pm	80	0.06	17.10	218	1.03	1.47	Low sunshine
6.15pm	84	0.04	16.60	217	0.66	0.94	Very low sunshine
6.30pm	84	0.01	14.06	217	0.14	0.20	No sunshine

Scientia Africana, Vol. 13 (No.1), June 2014. Pp 9-23
 ISSN 1118 - 1931

Table 2: The daily average readings from 70watts solar panel

Day	RH	I_{sc}	V_{oc}	Power	Efficiency
1	63.82	1.11	19.27	21.38	31.39
2	68.11	1.25	18.42	24.13	24.13
3	56.22	1.34	18.50	26.34	37.59
4	62.69	1.17	17.76	22.20	31.68
5	58.09	1.19	18.16	23.06	32.93
6	73.40	1.03	18.48	20.69	28.60
7	52.71	1.40	19.08	27.42	39.20
8	56.84	1.34	18.48	26.38	37.79

Table 3 shows the data collected on day 1 from 80watts automatic tracking solar panel. Table 4 shows the typical daily average readings for relative humidity, short-circuit current, open-circuit voltage, power and efficiency achieved from 80watts automatic tracking solar panel during the period of measurements.

Table 3: The data collected on day 1 (80 watts solar panel)

Time	Relative humidity	Isc	Voc	Vac	Power	Efficiency	Weather Remarks
7:30am	98	0.82	14.8	208	12.14	15.18	No Sun/Clear Sky.
7:45am	98	0.85	14.85	208	12.62	15.78	No Sun/Clear Sky.
8:00am	95	0.89	16.75	214	14.91	18.64	No Sun/Clear Sky.
8:15am	94	0.92	17.01	214	15.65	19.56	No Sun/Clear Sky.
8:30am	96	0.9	17	210	15.3	19.13	Rain Drops/Clear Sky.
8:45am	97	0.94	16.9	209	15.87	19.84	Rain Drops/Clear Sky.
9:00am	98	0.72	17.2	207	12.38	15.48	Rain Drops/Clear Sky.
9:15am	98	0.85	17.8	207	15.13	18.91	Rain Drops/Clear Sky.
9:30am	99	0.87	17.9	206	15.57	19.46	Slight Increase In Intensity.
9:45am	90	0.89	18.9	214	16.82	21.03	Slight Increase In Intensity.
10:00am	91	0.61	19.01	216	11.6	14.5	Slight Increase In Intensity.
10:15am	89	0.52	19.1	216	9.93	12.41	Moderate Sunshine.
10:30am	86	1.04	19.18	219	19.94	24.93	Moderate Sunshine.
10:45am	86	1.1	19.24	219	21.16	26.45	Moderate Sunshine.
11:00am	80	0.82	19.46	216	15.96	19.95	Moderate Sunshine.
11:15am	66	0.9	19.38	218	17.44	21.8	Moderate Sunshine.
11:30am	64	0.65	19.43	217	12.63	15.79	Moderate Sunshine.
11:45am	63	0.65	19.53	217	12.69	15.86	High Intensity.
12:00am	77	1.44	19.03	222	27.4	34.25	Moderate Sunshine.
12:15am	98	1.27	19.81	201	25.16	31.45	Moderate Sunshine.
12:30pm	78	2.46	19.73	210	48.54	60.68	High Intensity.
12:45pm	58	2.75	19.3	213	53.08	66.35	High Intensity.
1:00pm	61	2.15	19.9	205	42.79	53.49	High Intensity.
1:15pm	65	2.01	19.94	206	40.08	50.1	High Intensity.
1:30pm	54	2.52	19.25	210	48.51	60.64	High Intensity.
1:45pm	55	1.99	19.87	206	39.54	49.43	No Sun/Clear Sky.

2:00pm	82	0.99	18.54	213	18.35	22.94	No Sun/Clear Sky.
2:15pm	92	0.89	18.63	212	16.58	20.73	No Sun/Clear Sky.
2:30pm	91	1.14	18.99	219	21.65	27.06	Low Intensity.
2:45pm	88	0.74	19.34	205	14.31	17.89	Low Intensity.
3:00pm	86	1.04	19.51	219	20.29	25.36	Low Intensity.
3:15pm	76	0.89	19.61	221	17.45	21.81	Low Intensity.
3:30pm	76	1.58	19.69	218	31.11	38.89	Moderate Sunshine.
3:45pm	78	1.49	19.73	218	29.4	36.75	Moderate Sunshine.
4:00pm	86	0.38	18.47	198	7.02	8.78	No Sun/Clear Sky.
4:15pm	94	0.26	18.25	206	4.75	5.94	No Sun/Clear Sky.
4:30pm	99	0.13	17.12	208	2.23	2.79	Rainny.
4:45pm	100	0.1	16.63	207	1.66	2.08	Rainny.
5:00pm	100	0.07	13.24	206	0.93	1.16	Cloudy.
5:15pm	100	0.06	13.2	202	0.79	0.99	Cloudy.
5:30pm	100	0.05	12.63	203	0.63	0.79	Cloudy.
5:45pm	99	0.09	13.75	203	1.24	1.55	Cloudy.
6:00pm	100	0.06	13.85	204	0.83	1.04	Cloudy.

Table 4: The daily average readings from 80watts solar panel

Day	R.H %	Isc	Voc	Power	Efficiency
1	85.60	0.94	17.08	16.05	20.07
2	82.65	1.49	18.77	27.97	34.96
3	91	0.64	18.74	11.99	14.99
4	76	1.88	19.11	35.93	44.91
5	79	1.62	18.03	29.2	36.51
6	60	1.92	19.34	37.13	46.41
7	90	0.82	17.9	14.67	18.34
8	72	1.91	19.02	36.32	45.41
9	62	2.01	19.44	39.07	48.84
10	63	1.99	19.47	38.74	48.43
11	77	1.86	16.61	30.89	38.61
12	74	1.84	13.22	24.32	30.40

DISCUSSION

Current and Voltage against Time

For 70watts manually inclined solar panel, a graph of current and voltage against time of the day of data collection for day 1 shows that voltage and current increases between 7:30am and 8:30am (Figure 5). A steady decrease in both current and voltage was observed between the hours of 4:15pm and 6:30pm. A maximum current output of 2.22A was obtained at 12:30pm when the corresponding voltage at time of data collection was 19.91V. A graph of current and voltage against time of the day for day 2 (Figure 6) depicts that at early hours and evening hours of the day when the amount of moisture in the atmosphere is relatively high, both current and voltage values are low. The 80Watts automatic tracking solar panel shows similar trend as in Figure 5 and 6 for current and voltage against time of the day.

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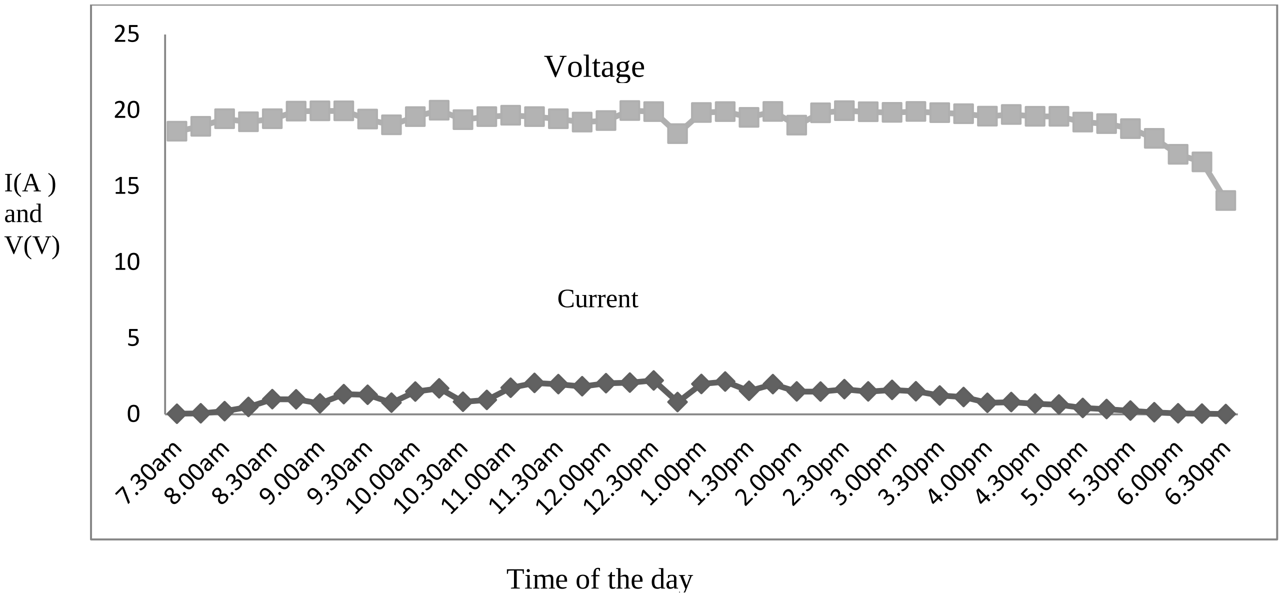

Figure 5: Current and voltage against Time for day 1using 70 Watts solar panel.

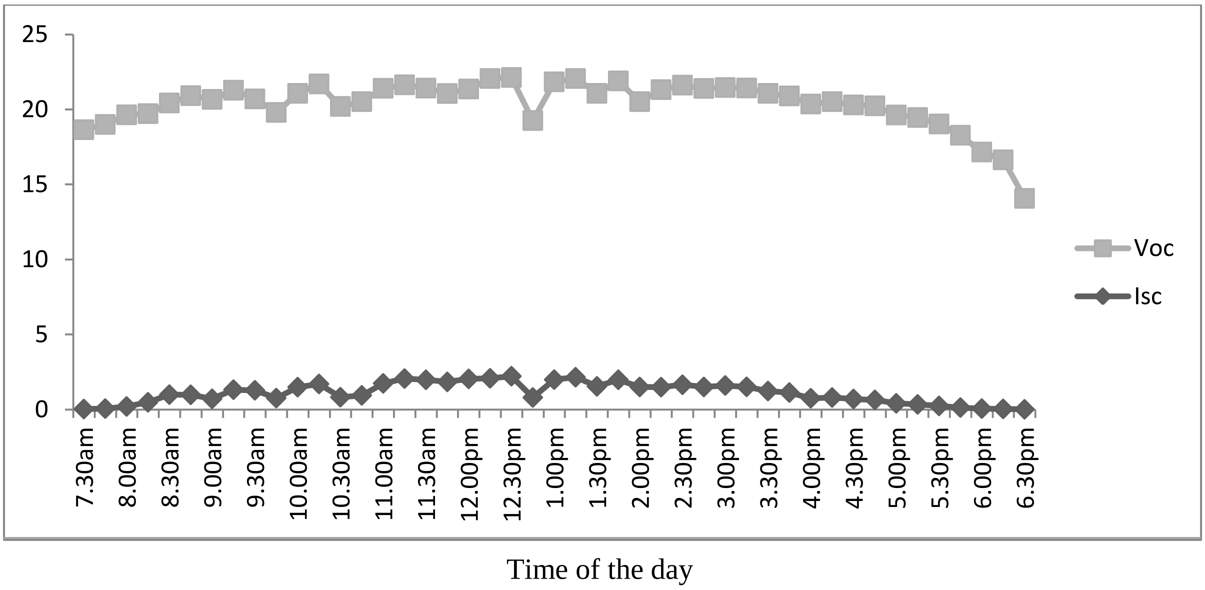

Figure 6: Current and voltage against Time for day 2 using 70 Watts solar panel.

I – V Characterisics

In Figure 7, the trend line shows that increase in current leads to increase in voltage at the early stage of data collection from inclined 70 Watts solar panel, but the voltage tends to be stable as current increases at later times. The maximum current obtained was 2.44A when the recorded open circuit voltage was 19.77V.

Figure 8 depicts that both current and voltage increases gradually initially, but voltage tend to fluctuate at later time of data collection. It was recorded that when the maximum current output of 2.22A was obtained, the open circuit voltage output was 19.84V.

For 80 Watts automatic tracking solar panel, a gradual increase in current leads to an increase in output voltaget but to an extent, with increase in current, voltages tends to be relatively constant. A maximum current of 2.75A is obtained when the voltage output is 19.30V (Figure 9). On day 10, the graph shows that there was a gradual increase in current and also gradual increase in voltage. At about 19V there is a continuous increase in current. A maximum current of 3.72A is obtained with a corresponding value of voltage to be 19.49V (Figure 10). I-V characteristics shows that a little increase in short circuit current produces high voltage output at early hours of the day and high current output leads to relatively stable voltage output.

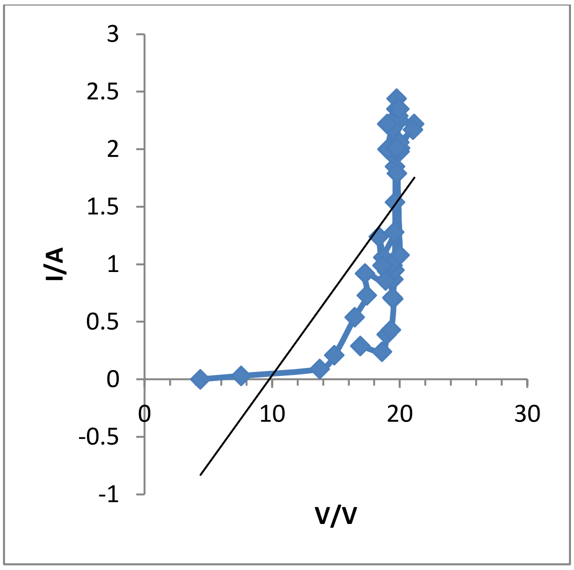

Figure 7: Ccurrent against voltage for day 3 from 70 Watts solar panel.

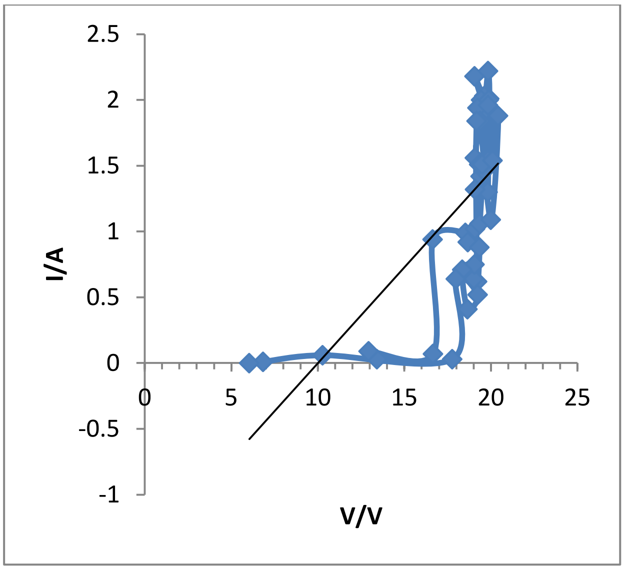

Figure 8: Current against voltage for day 5 from 70 Watts solar panel.

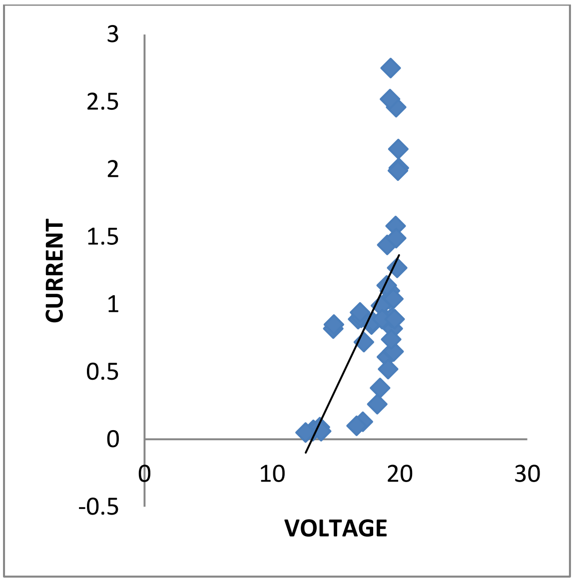

Figure 9: Current against voltage for day 1 from 80 Watts automatic tracked solar panel

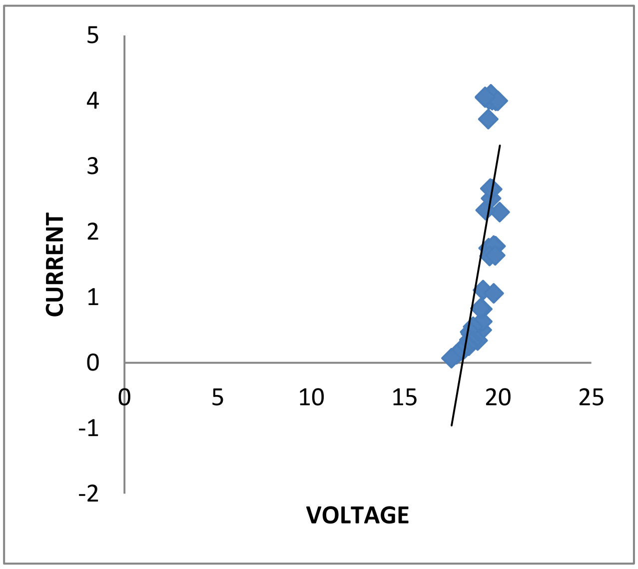

Figure 10: Current against voltage for day 10 from 80 Watts automatic tracked solar panel

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Output Power against Relative Humidity

For 70 watts inclined solar panel, Figure 11 shows that for day 3, at high relative humidity, power is observed to be low, while at low relative humidity when the amount of atmospheric moisture is reduced, output power tends to be high. A maximum power of 48.24 Watt was recorded when the relative humidity was 30% and the weather remark was assumed of high intensity at the time of data collection, while a minimum power output of 4.91 Watt was recorded when the relative humidity was 88%. Figure 12 shows that fluctuation in relative humidity causes a fluctuation in power output on day 4. A maximum power output of 48.85 Watt was recorded when the relative humidity was 55%. A graph of power against relative humidity for day 6 (Figure 13), shows that both power and relative humidity varied inversely to a certain limit when relative humidity tends to be relatively stable while output power increases. The maximum power obtained for the day was 58.4 Watt when the relative humidity was 52%. A graph of power against relative humidity characteristics for day 8 (Figure 14) shows that at the early hours of data collection, relative humidity was high while output power was very low. As relative humidity decreases, the output power increases. The low power output at the early hours of data collection can be assumed to be the effect of high moisture content in the atmosphere making the output short circuit current to be relatively low. A maximum power of 59.99 Watts, with an efficiency of 85.7% was recorded when the relative humidity was 30%.

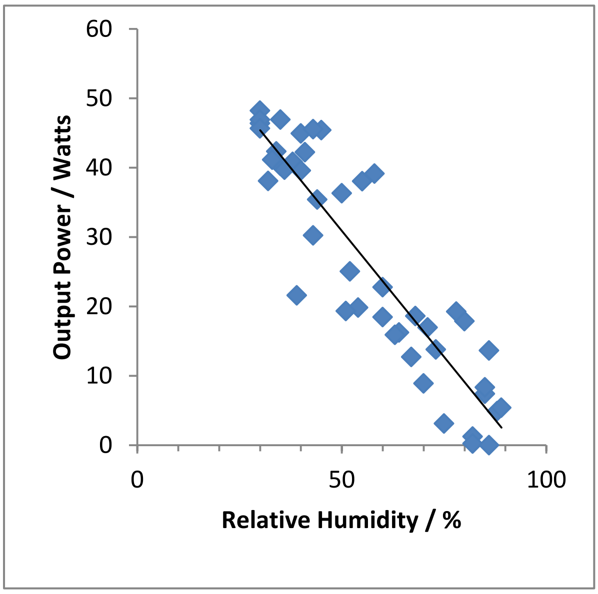

Figure 11: Output power against relative humidity for day 3 using 70 watts solar panel

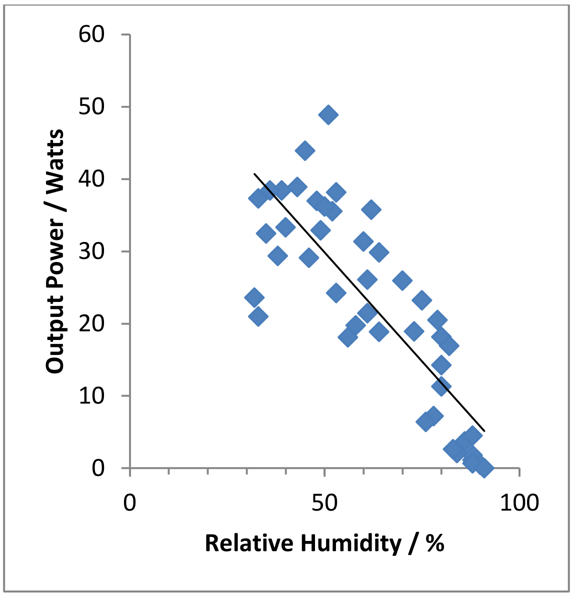

Figure 12: Output power against relative humidity for day 4 using 70 watts solar panel

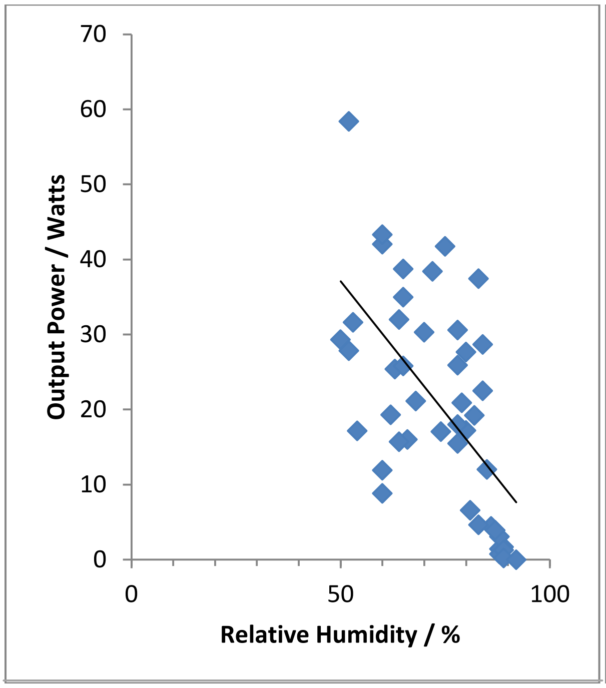

Figure 13: Output power against relative humidity for day 6 using 70 watts solar panel

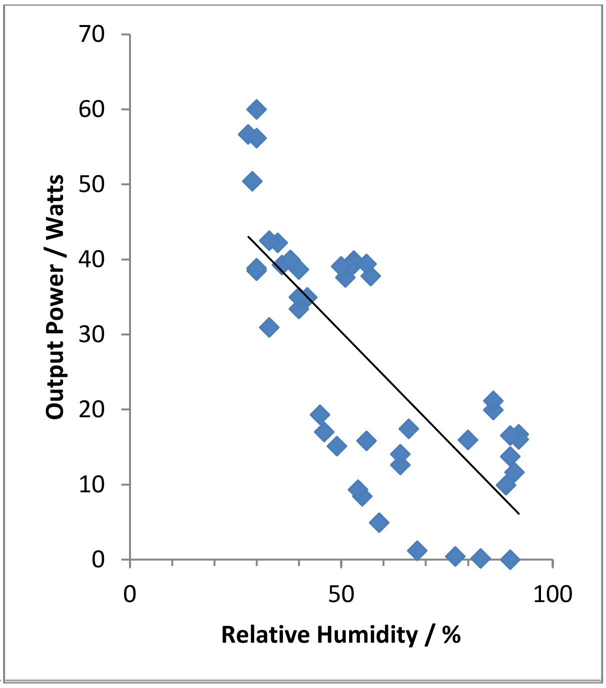

Figure 14: Output power against relative humidity for day 8 using 70 watts solar panel

For 80 watts automatic tracking solar panel, day 5 show that low humid air or atmosphere yielded increase in output power and high relative humidity yielded low output power. When relative humidity was at maximum 93%, the power output was 40.85watts and when it was minimum at 59% the power output was 59.85watts (Figure 15). This shows that output power varies inversely with the percentage relative humidity i.e.

$$p \propto \frac{1}{relativehumidity}$$

Similar trends were obtained in all the plots of output power versus relative humidity. The highest output power recorded was 77.20watts with a corresponding relative humidity of 41% while the lowest power output recorded was zero(0) watts with a corresponding relative humidity of 100% (Figure 16).

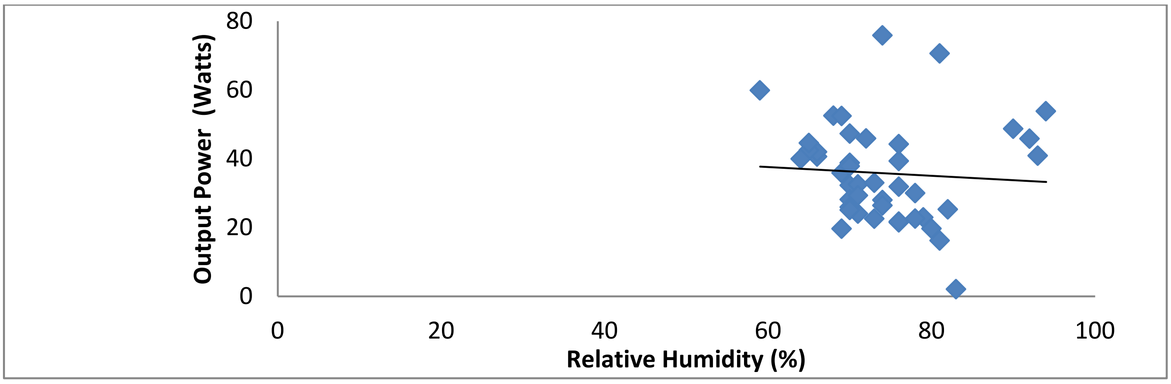

Figure 15: Output power against relative humidity for day 5 using 80 watts solar panel

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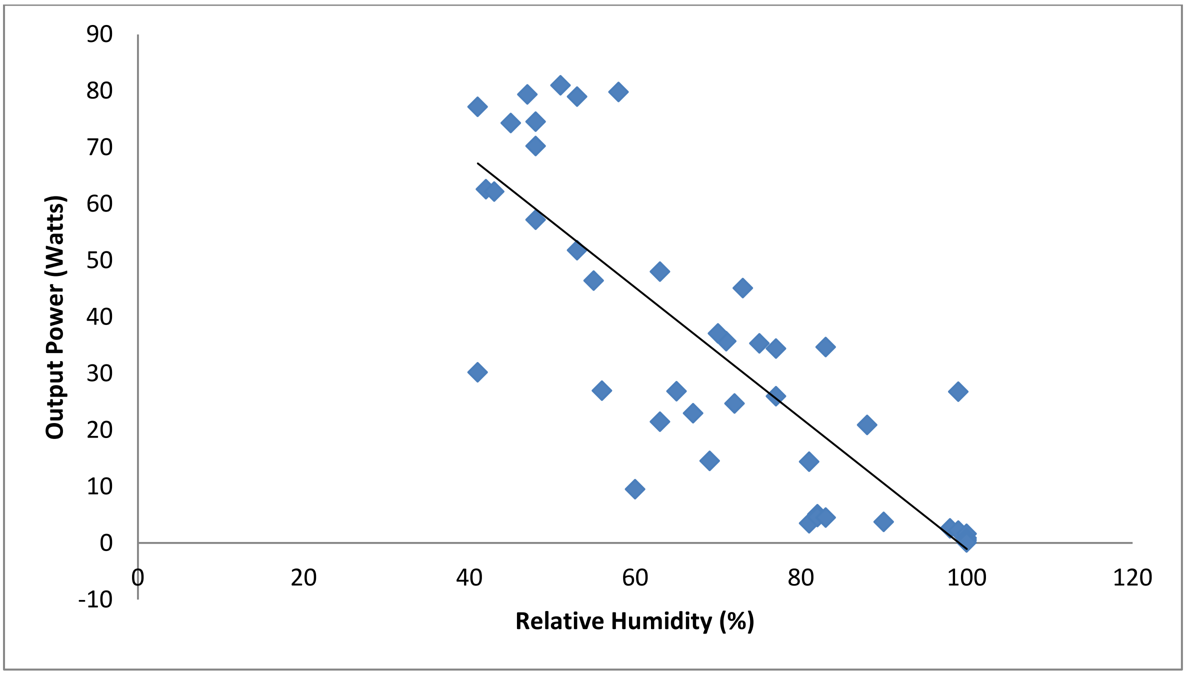

Figure 16: Output power against relative humidity for day 5 using 80 watts solar panel

The 70 watts inclined solar panel produced a percentage loss of 14% due to relative humidity when compared with the manufacturer's power rating while the 80 watts automatic tracking solar panel produced a percentage loss of about 3.50% when compared with the manufacturer's power rating of the solar panel.

The automatic solar tracker, thus, confirm that it is an efficient way for solar energy collection. This is evident through a little loss of power despite variations in relative humidity. The use of automatic solar tracker improves the efficiency by approximately 11% in the geographical location. Hence, high efficiency is obtained when automatic solar tracker is employed in solar power system.

Having studied the effect of relative humidity on the output performance of a solar power system in this geographical location, it is found that relative humidity has great effect on the performance of a solar power system. For 70 watts inclined solar panel, the maximum output power of 59.99watt was obtained when the relative humidity was 30%. The minimum output power of zero (0) watt was recorded when the relative humidity was 92%. For 80watts automatic tracking solar panel, the highest output power recorded was 77.20watts with a corresponding relative humidity of 41% while the lowest power output recorded was zero(0) watts with a corresponding relative humidity of 100%. This result shows an inverse proportionality beteen solar panel's output power and relative humidity. So, when the moisture contents in the atmosphere is high, low power output is obtained. Also, low relative humidity yielded high power output.

In addition, the 70 watts inclined solar panel produced a percentage loss of 14% due to relative humidity when compared with the manufacturer's power rating while the 80 watts automatic tracking solar panel produced a percentage loss of about 3.50% when compared with the manufacturer's power rating. The automatic solar tracker, thus, confirm that it is an efficient way for solar energy collection. This is evident through a little loss of power despite variations in relative humidity. The use of automatic solar tracker improves the efficiency by approximately 11% in the geographical location. Hence, high efficiency is obtained when automatic solar tracker is employed in solar power system. The application of photovoltaic technology in the conversion of solar energy to electricity within the region under study is favourable than in cool climate region.

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