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Experiment on Effects of Dust, Heat and Cloud on a Solar Energy Generation in South-Western Part of Nigeria

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Abstract **- Currently, the world at large (including industries, companies, homes, financial institutions, transport, agricultural sector and educational sector) is highly dependent on energy or power for its operations or daily activities but the society has started questioning how modern life is being powered. The world has started to look for better alternatives. So, as the technology is advancing, a continuous and uninterruptible power supply system has come into place on the platform of research, discoveries and creativities. This brought about the innovation of an alternative power supply system known as solar system but yet, different questions like what makes up the solar system? Do environmental factors affect the working of a solar panel? And how do atmospheric conditions affect the efficiency of a solar panel? This work has been able to proffer solutions to these bothering questions from the society by carrying out experiments on the effects of dust, heat and cloudy day on the solar panel.**
Keywords: **Cloud, Dust, Electricity, Generation, Heat, Solar**

I. INTRODUCTION

The solar power system is a system which generates electricity by making use of the sun's energy either directly as thermal energy (heat) or via the photovoltaic cells in solar panels. Solar panels literally consist of numerous, compact units of cells that convert sunlight into electricity. Solar panels are made up of solar cells which are an array of photovoltaic cells (PV),(1).A photovoltaic cell is a semiconductor device that converts solar radiation into direct current electricity,(2).“The Solar PV sector is rapidly developing new technologies for improving efficiency. As a general trend, efficiency and technology costs are directly proportional” (3). This work aimed at investigating effects of atmospheric factors and other natural factors on the working system of the solar panel.

In order to achieve the above defined objective, the scope used was that a solar backup system was set up and the following experiments were carried out on the solar panel (as a component part of a solar backup system):

1. Effects of dust on the solar panel
2. Effects of heat on the solar panel
3. Cloudy day study on the solar panel

The significance of this work is its relevancy to the advancing technology and it benefits the society by:

1. Exposing people’s knowledge to the proper maintenance of solar panel.
2. Increasing the variety of optional of home power system.

II. SOLAR POWER AND ENVIRONMENT DUST PARTICLES

A. Dust and Dirt Effect on the Solar Panel

This investigates the effects of dust particles on the performance of the solar panel. “Dust is probable to stick on to the array by Vander Waals adhesive forces. These forces are very strong at the dust particle sizes expected” (4). Dust can be generated on the solar panel by accumulation and pollution. “Further, due to dust accumulation on panel surface, short circuit current and open circuit voltage decreases” (5).“PV Dirt and dust can accumulate on the solar module surface. They block some of the sunlight from striking the cells and thereby reducing output performance of the panel.

Although typical dirt and dust is cleaned off during every rainy season, it is more realistic to estimate system output taking into account the reduction due to dust build up in the dry season” (6). The impaction of airborne dust having a wind velocity component perpendicular to the surface of the collector results in the collection of large particles. In such cases, there will be additional dust deposition caused by the impaction of particles aided by the electrostatic forces of adhesion if the particles are charged. In arid zones, most of the dust particles gain a significant magnitude of electrostatic charge during their erosion from the soil. The wind also causes removal of the deposited dust.

The dust removal rate at a relatively high wind speed will be more effective at a high tilt angle. Removal of the deposited dust also depends upon the particle diameter and the microstructure of the dust layer. A thin layer of dust deposited on a horizontal surface cannot easily be removed by wind, even at a relatively high velocity (50 m/s). The removal force, which is limited by the boundary-layer air velocity, has been found to be ineffective for particles with $d < 50$ lm when the free stream velocity is less than 50 m/s (5).

B. Heat Effect on the Solar Panel

Many may assume that more sun and hence more heat gives in more electricity but this assumption is absolutely invalid. Photovoltaic (PV) semiconductors propound supplementary resistance in maximal heat, which makes them under effective instead of being most efficient. Though, this extra resistance is minute but it limits the efficiency of the solar panel but recent technologies (such as thin-film PVs), which is not dependent on crystalline silicon to give electricity are slighter liable to heat-related efficiency losses. "The solar heating systems for industrial applications have a great potential to reduce the demand for conventional energy" (7).

C. Cloudy Day Study on the Solar Panel

Light is directly proportional to power, therefore as the solar panel receive more direct light, more power will be produced and decrease in direct light yields decrease in amounts of power generated from the solar panel. So, a bright/sunny day will add to the solar panel's working capacity but thick cloudy day will give lower power production. Aside straight light, solar panels will also suck up diffused/reflective light. An instance of diffused light is when a cloud briefly covers the sun and yet light is still gotten from the entire sky. Solar panels can likewise absorb reflective light from shiny or light-coloured facets.

D. Socio-Economic Benefit of the Solar Panel

Below is the socio-economic significance of the solar panel:

1. provision of significant work opportunities;
2. diversification and security of energy supply;
3. support of the deregulation of energy markets;
4. Acceleration of the rural electrification in developing countries" (8).

E. Return Son Solar Panels

1. The invention of the solar panel brought about an advancement in the technology.
2. One can get money from the PHCN for generating surplus electricity that they can re-distribute, or get a rebate from the PHCN for installing a solar power system (depending on where you live); thus, it makes the society become independent on the PHCN for electricity. Also, they provide lesser energy bills; hence they are economy friendly.
3. They are used for backup in case of power failure or blackout.
4. The maintenance cost of the solar panel is at a minimum because the maintenance requirement is not excessive. No part is relatively needed to be changed except for the inverter which can last within the range of five to ten years before replacement.
5. Solar cells are absolutely silent because they can draw out energy from the sun without making a bit of noise.
6. Solar Panels price is at the present moment on a swift diminishing track; and it is predicted to keep on reducing for the succeeding years.
7. There is no leakage problem as no leaky fluids are used in its design.
8. They provide renewable energy (i.e. the energy can be used to generate both heat and electricity in the home).

F. Detriments of Solar Panels

1. They require more space in case of installing a larger and numerous one especially if the roof is not big enough to accommodate the panels
2. Solar panels are unreliable because they cannot store energy at night and since they are sun-dependent, they cannot operate at a maximum.
3. The cost of energy storage is expensive since battery will be needed.
4. Solar panels cause pollution because their installation and transportation contributes to the emission of green gases in the atmosphere.
5. The purchase of the battery, inverter, charge controller alongside with the solar panel coupled with their installation is expensive

G. Area of Applications of Solar Panels

Solar panels are applied in various devices used at homes, offices, hotels, schools, financial institutions etc. Below are some of their applications:

1. They are used for charging of electronic devices such as laptop, mobile phones, battery, torchlight, etc.
2. They are used in (day-to-day) electronic devices such as calculators, toys, flashlight, watches, radio, MP3 players etc. "Even some ATMs (machines that let you get money from or put money into your bank account) have solar panels"(9)
3. They are used for weapons systems, missiles, implanted medical devices etc.
4. They are used on roads to construct highways. Also, "solar panels are sometimes used to make the electricity to light up road signs and bus stops. They may make the electricity that makes roadside emergency phones or parking meters' work"(9)
5. They are also used in automobiles for solar-powered cars or vehicles and airplanes
6. They are also used for powering devices such as solar-pumped lasers, photovoltaic power stations and solar hybrid power systems.
7. They are used for standalone photovoltaic (PV) systems and rooftop solar PV systems.

III. EXPERIMENTAL MATERIALS SPECIFICATIONS AND PROCEDURAL SET-UP

This section reveals the methods used in carrying out these distinct experiments. The procedures, equipment, etc., used for each experiment are also outlined in this section.

A. Required Materials

The materials required for all the experiments performed in this work are:

1. *Solar Panel:* It is good to know that "the amount of power that a PV solar panel provides is indicated by the wattage (W). The higher the wattage, the more powerful the panel" (10). For all the experiments carried out in this work, two solar panels were used: the 80W and 5W solar panels. A mono-crystalline 80W solar panel used in this work. The dirt/dust effect and cloudy day study was done on it.
2. *Solar Power Inverter:* A solar power inverter that has the following specifications:
   Wattage: 1000W
   Voltage: DC 12V to AC 230V, AC 210V-230V
   SAA-1000A
3. *Deep Cycle Battery:* One deep cycle battery that has the following specifications:
   Model: 12V40AH
   Cycle Use: 14.4-15V
   Standby Use: 13.6-13.8V
   Initial Current less than 11.4A
   Weight: 13 KGS
   Size: 203x175x225mm
   Features:
   Extra thick plate with Pb-Ca Tin alloy
   Sealed, maintenance-free operation
   Patent design for terminal without leakage
   Anti-corrosion electrolyte ensures longer life.
4. *Solar Charge Controller:* One solar charge controller that has the following specifications:
   Voltage: 12V/24V
   Current: 30A
   Features:
   LCD display
   PWM battery charging
   All necessary protections equipped
   Adjustable controlling parameter of the systems
5. *Digital Multimeter:* Three digital multimeter that has the following features:
   It has a battery to power the display. So, it uses virtually no power from the circuit under test.
   It has a digital display as shown in figure 5.
   It has auto power off.
6. *Iron:* An electric iron; it is used for heat effect on the solar panel.
7. *Direct sunlight*
8. *Wires*

IV. RESULTS AND DISCUSSION

This section gives a thorough and topical discussion on the experiments carried out on the solar panel.

A. Dust and Dirt Effect on the Solar Panel
Initial Voltage: 13.6V
Initial Current: 1.0A

TABLE I DUST/DIRT EFFECT ON THE SOLAR PANEL

Dust Quantity	Voltage (V)	Current (A)	Power (W)
No dust (Initial Voltage)	13.6	1.0	13.6
Little dust	13.3	0.6	7.98
More dust	13.2	0.4	5.28
More dust	12.9	0.2	2.58

Table I shows the readings gotten from dust/dirt effects on the solar panel. It is observed that the voltage and the current drastically reduced from 13.6V and 1.0A to 12.9V and 0.2A respectively. Table II shows the statistical analysis of the dust/dirt effects on the solar panel.

Figure 1 illustrated that there is a drop in the voltage and current on the solar panel. Hence, an increase in dust quantity yields a drop in the voltage and current flow. There is more correlation between the voltage and current flow with equal correlation between the current and power output.

The below results have proven that there is an adverse effect of dust and dirt on the solar panel depending on its thickness on the panel.

TABLE II STATISTICAL TABLE FOR DUST/DIRT EFFECT ON SOLAR PANEL

Variable	Dust Quantity	Voltage (V)	Current (A)	Power (W)
Numeric values	0	4	4	4
Text values	4	0	0	0
Missing values	0	0	0	0
Unique values	3	4	4	4
Zero values	0	0	0	0
Most frequent	More dust			
Min. value		12.9	0.2	2.58
Max. value		13.6	1	13.6
Median		13.45	0.8	10.79
Mean value		13.25	0.55	7.36
Std. deviation		0.25	0.295803989	4.077278504
2σ outliers		0	0	0
3σ outliers		0	0	0
4σ outliers		0	0	0

Table I shows the readings gotten from dust/dirt effects on the solar panel. It is observed that the voltage and the current drastically reduced from 13.6V and 1.0A to 12.9V and 0.2A respectively. Figure 2 and Figure 3 illustrated that there is a drop in the voltage and current on the solar panel.

The above results have proven that there is an adverse effect of dust and dirt on the solar panel depending on its thickness on the panel.

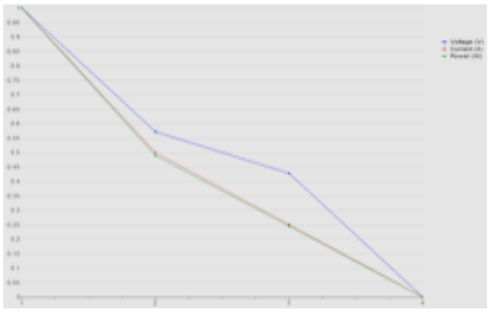

Fig. 1 Dust/Dirt Effects on Solar Panel

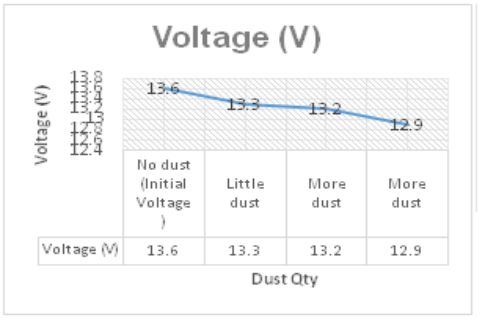

Fig. 2 Dirt/Dust Effect Readings for Voltage (Field Data)

B. Heat Effect on the Solar Panel

Initial Voltage: 1.74V (No heat)
Initial Current: 0.07A (No heat)

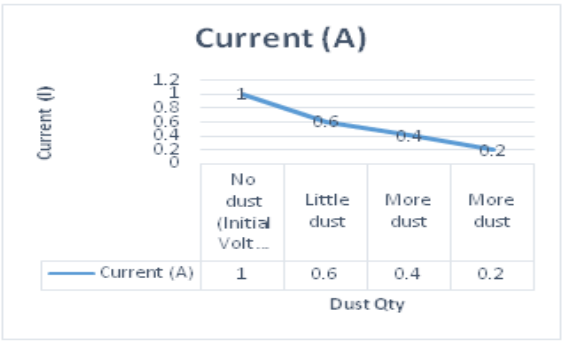

Fig. 3 Dirt/Dust Effect Readings for Current (Field Data)

TABLE III HEAT EFFECT ON THE SOLAR PANEL

Time (Minutes)	Voltage (V)	Current (A)	Power (W)
No heat	1.74	0.07	0.1218
10	1.7	0.05	0.085
20	1.49	0.05	0.0745
30	1.46	0.04	0.0584
40	1.44	0.04	0.0576
50	1.35	0.04	0.054

TABLE IV STATISTICAL TABLE FOR HEAT EFFECTS ON THE SOLAR PANEL

Variable	Time (Minutes)	Voltage (V)	Current (A)	Power (W)
Numeric values	5	6	6	6
Text values	1	0	0	0
Missing values	0	0	0	0
Unique values	6	6	3	6
Zero values	0	0	0	0
Most frequent			0.04	
Min. value	10	1.35	0.04	0.054
Max. value	50	1.74	0.07	0.1218
Median	30	1.595	0.05	0.07975
Mean value	30	1.53	0.048333333	0.075216667
Std. deviation	14.14213562	0.141421356	0.010671874	0.023485912
2σ outliers	0	0	1	0
3σ outliers	0	0	0	0
4σ outliers	0	0	0	0

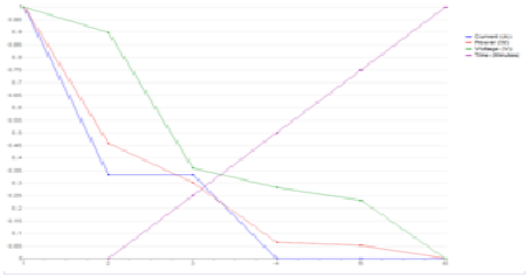

Fig. 4 Heat Effect on the Solar panel (Field Data)

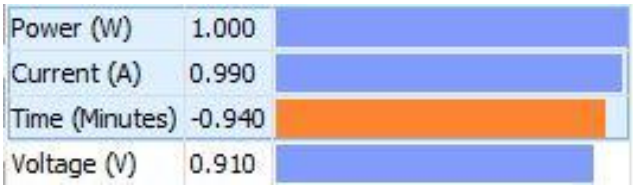

Fig. 5 Correlation Chart between Time and Power (W)

Table III shows the readings gotten from dust/dirt effects on the solar panel. It is observed that the voltage and the current dropped from 1.74V and 0.07A to 1.35V and 0.04A respectively. Table IV shows the statistical analysis of the heat effects on the solar panel. Figure 4 illustrated that voltage and current drop is minimal when the heat is applied on the solar panel. Hence, an increase in heat yields a drop in the voltage and current flow. Figure 5 illustrated the correlation between the dust quantity and the output power (W) of the solar panel; there is a close correlation between

all the variables. The above results have proven that heat has a depreciating effect on power output generated by the solar panel.

Table V shows the readings gotten from dust/dirt effects on the solar panel. It is observed that the voltage and the current dropped from 1.74V and 0.07A to 1.35V and 0.04A respectively. Figure 6 illustrated that voltage and current drop is minimal when the heat is applied on the solar panel. The above result has proven that heat has a depreciating effect on power output generated by the solar panel.

TABLE V HEAT EFFECT ON THE SOLAR PANEL

Time (Minutes)	Voltage (V)	Current (A)	Power (W)
No heat	1.74	0.07	0.1218
10	1.7	0.05	0.085
20	1.49	0.05	0.0745
30	1.46	0.04	0.0584
40	1.44	0.04	0.0576
50	1.35	0.04	0.054

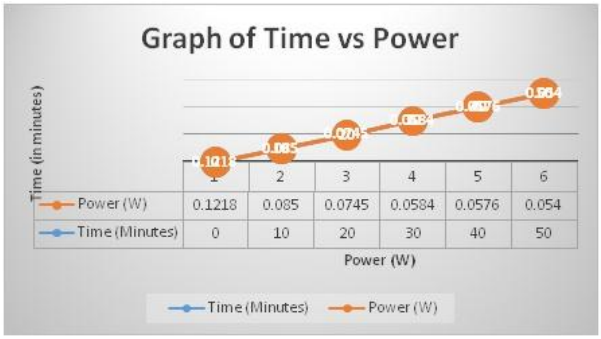

Fig. 6 Heat Effect on the Solar panel (Field Data)

C. Cloudy Day Study on the Solar Panel

TABLE VI CLOUDY DAY STUDY ON THE SOLAR PANEL

Time	Voltage (V)	Current (A)	Power (W)	PV (Solar)	PV (Load)
10:00 am	13.3	1.2	15.96	0025	0005
11:00 am	13.2	1.1	14.52	0025	0005
12:00 pm	13.2	1.1	14.52	0024	0005
01:00 pm	13.2	1.1	14.52	0022	0005
02:00 pm	13.1	1.0	13.1	0021	0005
03:00 pm	12.8	0.7	8.96	0021	0005

TABLE VII STATISTICAL TABLE FOR CLOUDY DAY STUDY ON THE SOLAR PANEL

Variable	Voltage (V)	Current (A)	Power (W)	PV (Solar)
Numeric values	6	6	6	6
Text values	0	0	0	0
Missing values	0	0	0	0
Unique values	4	4	4	4
Zero values	0	0	0	0
Most frequent	13.2	1.1	14.52	21
Min. value	12.8	0.7	8.96	21
Max. value	13.3	1.2	15.96	25
Median	13.2	1.1	14.52	24.5
Mean value	13.1333 3333	1.03333 3333	13.5966 6667	23
Std. deviation	0.15986 1051	0.15986 1051	2.23190 2527	1.73205 0808
2σ outliers	1	1	1	0
3σ outliers	0	0	0	0
4σ outliers	0	0	0	0

Fig.7 Cloudy Day Study on the Solar Panel (Field Data)

Table VI shows the readings gotten from the cloudy day study on the solar panel. It is observed that the voltage and the current dropped from 13.3V and 1.2A to 12.8V and 0.7A respectively.

Table VII shows the statistical analysis of cloudy day study on the solar panel. Figure 7 illustrated that voltage and current drop is minimal when the heat is applied on the solar panel. Hence, an increase in heat yields a drop in the voltage and current flow. Figure 5 illustrated that there is an equal correlation between the voltage, current and power output of the solar panel.

The above results have proven that a cloudy weather has a depreciating effect on power output generated by the solar panel.

TABLE VIII CLOUDY DAY STUDY ON THE SOLAR PANEL

Time	Voltage (V)	Current (A)	Power (W)	PV (Solar)	PV (Load)
10:00 am	13.3	1.2	15.96	0025	0005
11:00 am	13.2	1.1	14.52	0025	0005
12:00 pm	13.2	1.1	14.52	0024	0005
01:00 pm	13.2	1.1	14.52	0022	0005
02:00 pm	13.1	1.0	13.1	0021	0005
03:00 pm	12.8	0.7	8.96	0021	0005

Table VIII shows the readings gotten from the cloudy day study on the solar panel. It is observed that the voltage and the current dropped from 13.3V and 1.2A to 12.8V and 0.7A respectively. Figure 8 illustrated that voltage and current drop is minimal in a cloudy weather. The above result has proven that a cloudy weather has a depreciating effect on power output generated by the solar panel.

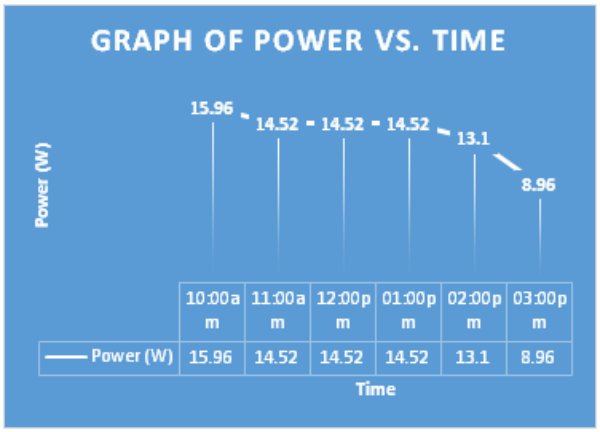

Fig. 8 Cloudy Day Study on the Solar Panel (Field Data)

V. CONCLUSION

This paper concludes that both the cloudy day study and dust effect experiment on the solar panel leads to a deficiency in the energy generation of the solar panel, depending on the brightness of the cloud and dust respectively i.e. the solar panel will not receive much energy from the sun due to the thickness of the cloud and dust respectively. For the heat effect, photovoltaic semiconductors give more resistance in severe heat which makes them less efficient rather than being most efficient.

This work can be improved by keeping to the following recommendation:

1. Experiments on other effects of atmospheric conditions like wind, humidity, rainfall etc. can be carried out on the solar panel.
2. There should be expository classes on the effects of atmospheric conditions on the solar panel so as to have a better maintenance routine of the solar panel.
3. Government can include the topic of this work in the Engineering Technology course curriculum

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