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RESEARCH ARTICLE

Preliminary investigation of Solar Insolation in Ihite Uboma LGA of Imo state, South East Nigeria – using a photoresistor arrangement

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ABSTRACT

In this work a preliminary investigation of the average daily solar insolation in Ihite Uboma LGA of Imo State, South East Nigeria, has been made. Method employed the use of the correlation between solar insolation and the solar resistance of a cadmium sulphide photoresistor cell mounted within the locality. Experiment suggests that the location has average daily insolation figure of about 10.0kWhm^{-2} per day. In comparison with NASA's report of 2002, the LGA appears to fall within the high radiation zone of the globe and so can support solar projects. This investigation is informative and should attract the attention of both government and non-governmental agencies that are interested in solar energy harvesting for domestic and industrial use as well as the global battle against CO_2 emissions.

INTRODUCTION

From a distance of about 150 million km radiates the sun's enormous energy on the earth's atmosphere, amounting to a solar constant of 1.36kWm^{-2} (Duffie, 1995). On a clear day the atmosphere may transmit only 90% of this value while on a cloudy day the atmosphere may transmit only 10%. According to Duffie (1995), the average amount of solar energy reaching the ground has a maximum intensity of about 1.2kWm^{-2}. This manifests mostly as visible light; a fraction of it manifests in the infrared region while a small percentage manifests in the ultraviolet region. However most developing countries according to Mumah *et al.,* (1991) occupy the areas that fall in the high radiation receiving zone of the globe. Wilson (2003) reported that solar radiation received on earth has been increasing since the late 19th century. Our background radiation is particularly increased according to Avwiri *et al.,* (1998) by the increasing amount of cosmic rays reaching the earth's surface as a result of depletion of ozone layer. To say that solar energy has been in use for ages is perhaps an understatement. Rather what should be said in the present dispensation is that global effectiveness in harnessing the resource should be emphasized. Its environmentally friendly nature has no doubt placed it at the forefront in the global battle against CO_2 emissions as specified by the Kyoto protocol. This fact was demonstrated by Lenius *et al.,* (2005). Solar Insolation is the amount of solar energy that is incident on the earth's surface per unit area per day. It is usually expressed in kWhm^{-2} per day or MJm^{-2} per day. Insolation figure of a location is usually necessary before selecting a site for photovoltaic and other solar energy systems. For instance if solar collectors are to be mounted, locations with low insolation level will require collectors of larger areas than those with higher insolation values. Furthermore, daily insolation is a necessary figure of merit when designing and sizing solar energy systems in any locality. At the time of this report there was no known solar data or record kept on Ihite Uboma Local Government Area of Imo State.

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Theoretical Background

The correlation between solar insolation and photo-resistance is expressed in terms of natural logarithm as:

$$Ln(I)=6.32 - 0.98Ln(R) \qquad - \qquad (1)$$

Where: I=Insolation and R = Solar resistance But natural logarithm Ln = 2.303log$_{10}$.

Therefore applying this in equation (1) we have:-

$$2.303\log_{10}(I) = 6.32-(0.98 \times 2.303\log_{10}(R)$$

$$\text{Therefore, } Log_{10}(I)= \frac{6.32}{2.303} - 0.98\log_{10}(R)$$

$$Log_{10}(I) + \log_{10}(R^{0.98)} = 2.7442$$

$$\text{Thus: } Log_{10}(IR^{0.98}) = 2.7442 \qquad - \qquad (2)$$

$$\text{Hence } IR^{0.98}= 10^{2.7442}$$

$$\text{Giving: } I=10^{2.7442}/R^{0.98} \qquad - \qquad (3)$$

In terms of given area of surface, equation (3) can be expressed as:-

$$I = \frac{10^{2.7442}/R^{0.98}}{A} Whm^{-2} \qquad - \qquad (4)$$

Where A is the surface area of the photo resistor. Equation (4) is in Whm^{-2} and the photo resistor used for this work has a surface area of 5.7279 x 10^{-4}m^2. According to the report of the American National Aeronautics and space Administration (NASA, 2002), the global scale that provides a basic guide for insolation level is shown in Fig 1. The scale shows the insolation level in kWhm^{-2} per day. It is divided into three regions as low, moderate and high. From the scale, areas with insolation values of 4kWhm^{-2} per day and below fall within the low insolation zone. Those having values between 4 and 5kWhm^{-2} per day fall within the moderate insolation zone while those that have values of 5kWhm^{-2} per day and above fall within the high insolation zone of the globe. The communities in such areas receive abundance of solar energy and should therefore harness the resource.

MATERIALS AND METHODS

Materials used for this work include cadmium sulphide (cds) photo resistor of a negative coefficient, digital ohm-meter and a solar stand. Daily insolation can be measured using the correlation between solar insolation and sunshine hours or between solar insolation and zenith angle. In this work insolation was measured by using its correlation with photoresistance. The cadmium sulphide photoresistor was mounted on a solar stand, inclined at a tilt angle of 5^0 to the horizontal which corresponds to the angle of the latitude of the location. This approach was informed by the method suggested by Ojosu (2001) who reported that the tilt angle to the horizontal should be the latitude of the site. The readings of the photo resistances were taken at hourly intervals from 8 am to 4 pm each day using a digital ohm-meter. This continued for many days. From the solar resistance values, the solar insolation for each hour was determined according to equations (3) and (4). Table 1 shows the measured values of solar resistance and the determined values of solar insolation for the period.

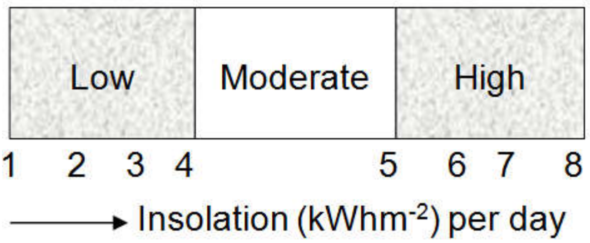

Fig. 1. Basic Scale for Global Insolation Level as published by NASA (2002)

Table 1. Daily Data Obtained

Day	Time	Solar Resistance (Ω)	Solar Insolation (kWhm^{-2})
	8:00	306.30	3.54
	9:00	200.50	5.38
	10:00	182.40	5.90
1	11:00	96.00	11.07
	12:00	87.70	12.10
	1:00	68.30	15.45
	2:00	89.70	11.84
	3:00	90.40	11.75
	4:00	107.00	9.95
	8:00	216.20	4.89
	9:00	102.00	10.42
	10:00	90.60	11.71
	11:00	80.20	13.20
2	12:00	52.70	19.92
	1:00	48.80	21.49
	2:00	90.90	11.68
	3:00	128.50	8.31
	4:00	236.40	4.57
	8:00	315.40	3.46
	9:00	205.10	5.25
	10:00	102.20	10.41
	11:00	92.00	11.54
3	12:00	86.00	12.33
	1:00	71.30	14.82
	2:00	52.90	19.85
	3:00	62.90	16.81
	4:00	201.60	5.34
	8:00	431.40	2.53
	9:00	130.00	8.22
	10:00	100.80	10.54
	11:00	85.30	12.43
4	12:00	68.00	15.52
	1:00	60.20	17.49
	2:00	96.70	11.00
	3:00	152.80	7.02
	4:00	215.40	5.01
	8:00	352.10	3.09
	9:00	200.50	5.38
	10:00	153.60	6.98
	11:00	192.40	5.60
5	12:00	100.90	10.54
	1:00	92.00	11.54
	2:00	80.90	13.09
	3:00	63.10	16.71
	4:00	96.60	11.23
	8:00	243.50	4.45
	9:00	100.50	10.58
	10:00	92.40	11.49
	11:00	77.70	13.62
6	12:00	69.10	15.28
	1:00	67.00	15.75
	2:00	95.60	11.12
	3:00	121.50	8.78
	4:00	118.36	9.01
	8:00	148.50	7.22
	9:00	130.50	8.19
	10:00	106.00	10.04
	11:00	90.00	11.78
7	12:00	86.00	12.33
	1:00	74.10	14.26
	2:00	60.20	17.49
	3:00	192.30	5.60
	4:00	238.00	4.54
	8:00	210.00	5.13
	9:00	105.00	10.14
	10:00	90.10	11.78
	11:00	95.20	11.16
8	12:00	90.50	11.73
	1:00	85.00	12.47
	2:00	99.70	10.67
	3:00	200.20	5.39
	4:00	315.00	3.46
	8:00	482.60	2.27
	9:00	310.70	3.51
	10:00	95.50	11.12
9	11:00	98.20	10.82
	12:00	100.90	10.54
	1:00	52.20	20.11
	2:00	63.80	16.52
	3:00	185.70	5.80
	4:00	390.50	2.79
	8:00	205.40	5.25
	9:00	163.00	6.58
	10:00	95.70	11.10
	11:00	86.90	12.20
10	12:00	80.00	13.23
	1:00	74.80	14.14
	2:00	131.70	8.12
	3:00	78.10	13.55
	4:00	116.80	9.13
	8:00	201.30	5.35
	9:00	105.20	10.11
	10:00	103.50	10.27
	11:00	80.10	13.20
11	12:00	68.20	15.46
	1:00	58.50	17.96
	2:00	89.30	11.87
	3:00	170.70	6.29
	4:00	208.90	5.18
	8:00	310.10	3.50
	9:00	208.50	5.17
	10:00	186.20	5.78
	11:00	98.40	10.79
12	12:00	85.20	12.43
	1:00	70.30	15.00
	2:00	88.50	11.97
	3:00	92.40	11.48
	4:00	110.00	9.67
	8:00	226.00	4.78
	9:00	120.20	8.87
	10:00	98.40	10.79
	11:00	86.50	12.24
13	12:00	68.20	15.46

	1:00	54.80	19.15
	2:00	99.50	10.67
	3:00	124.20	8.59
	4:00	230.10	4.69
	8:00	330.20	3.29
	9:00	140.50	7.61
	10:00	102.10	10.41
	11:00	92.30	11.49
14	12:00	68.50	15.39
	1:00	61.40	17.13
	2:00	100.20	10.60
	3:00	150.00	7.14
	4:00	221.20	4.88
	8:00	361.20	3.02
	9:00	209.40	5.15
	10:00	145.50	7.36
	11:00	180.20	5.96
15	12:00	98.80	10.75
	1:00	87.30	12.13
	2:00	78.20	13.52
	3:00	65.40	16.10
	4:00	102.50	10.37
	8:00	240.20	4.50
	9:00	102.50	10.37
	10:00	98.40	10.79
	11:00	82.50	12.83
16	12:00	70.20	15.02
	1:00	73.50	14.36
	2:00	97.80	10.86
	3:00	130.40	8.19
	4:00	140.20	7.63
	8:00	461.20	2.37
	9:00	280.40	3.87
	10:00	100.50	10.57
	11:00	98.80	10.75
17	12:00	90.50	11.71
	1:00	68.20	15.46
	2:00	74.80	14.12
	3:00	130.20	8.20
	4:00	148.00	7.23
	8:00	210.100	5.13
	9:00	167.20	6.42
	10:00	98.50	10.78
	11:00	89.20	11.88
18	12:00	82.50	12.83
	1:00	72.60	14.54
	2:00	128.40	8.31
	3:00	112.50	9.46
	4:00	120.40	8.86
	8:00	318.20	3.42
	9:00	200.40	5.37
	10:00	110.00	9.67
	11:00	96.20	11.03
19	12:00	84.50	12.53
	1:00	78.40	13.48
	2:00	65.20	16.15
	3:00	76.90	13.74
	4:00	160.20	6.69
	8:00	248.10	4.36
	9:00	115.20	9.25
	10:00	96.40	11.01
	11:00	80.10	13.20
20	12:00	70.00	15.07
	1:00	68.50	15.39
	2:00	100.10	10.61
	3:00	118.40	9.00
	4:00	124.20	8.59
	8:00	160.00	6.70
	9:00	142.40	7.51
	10:00	115.20	9.25
	11:00	94.50	11.23
21	12:00	88.10	12.03
	1:00	70.50	14.96
	2:00	63.40	16.60
	3:00	120.30	8.86
	4:00	210.40	5.12
	8:00	250.00	4.33
	9:00	130.00	8.21
	10:00	105.40	10.09

	11:00	95.60	11.10
22	12:00	90.70	11.69
	1:00	87.40	12.12
	2:00	100.10	10.61
	3:00	218.20	4.94
	4:00	280.00	3.87
	8:00	230.00	4.70
	9:00	100.00	10.62
	10:00	92.50	11.47
	11:00	96.10	10.99
23	12:00	91.00	11.65
	1:00	88.20	12.01
	2:00	106.10	10.02
	3:00	220.50	4.89
	4:00	301.20	3.61
	8:00	150.20	7.13
	9:00	130.10	8.21
	10:00	101.40	10.48
	11:00	95.20	11.15
24	12:00	89.10	11.89
	1:00	78.40	13.48
	2:00	67.50	15.61
	3:00	186.20	5.78
	4:00	255.00	4.24
	8:00	320.20	3.40
	9:00	210.50	5.12
	10:00	170.10	6.31
	11:00	98.00	10.83
25	12:00	86.20	12.29
	1:00	69.50	15.28
	2:00	75.20	14.04
	3:00	102.40	10.38
	4:00	118.50	8.99
	8:00	243.20	4.45
	9:00	125.40	8.51
	10:00	96.50	11.00
	11:00	84.20	12.57
26	12:00	60.80	17.30
	1:00	55.20	19.02
	2:00	94.20	11.26
	3:00	124.50	8.57
	4:00	280.00	3.87
	8:00	300.00	3.62
	9:00	215.20	5.01
	10:00	108.50	9.81
	11:00	98.20	10.81
27	12:00	85.30	12.41
	1:00	79.20	13.35
	2:00	65.10	16.18
	3:00	69.50	15.17
	4:00	226.00	4.78
	8:00	400.10	2.73
	9:00	180.20	5.96
	10:00	122.40	8.71
	11:00	90.00	11.78
28	12:00	74.20	14.23
	1:00	62.50	16.84
	2:00	100.00	10.62
	3:00	145.20	7.37
	4:00	218.40	4.94
	8:00	350.00	3.11
	9:00	215.20	5.01
	10:00	175.40	6.12
	11:00	190.30	5.65
29	12:00	102.50	10.37
	1:00	96.20	11.03
	2:00	84.00	12.60
	3:00	70.50	14.96
	4:00	98.00	10.83
	8:00	240.00	4.50
	9:00	105.20	10.11
	10:00	90.30	11.74
	11:00	81.20	13.03
30	12:00	73.40	14.38
	1:00	69.50	15.17
	2:00	92.30	11.49
	3:00	118.20	9.02
	4:00	124.20	8.59
			Av = 9.98

RESULTS AND DISCUSSION

The trend of the solar resistance data obtained showed that solar resistance of the cadmium sulphide cell varied with solar intensity. Consequently the solar insolation of the day varied with solar intensity. Since the cell was of a negative coefficient, the solar resistance increased with low solar intensity while decreasing with high intensity. As expected, insolation for most of the days assumed maximum values within the hours of 10am to 2pm. So far the average insolation figure obtained within the period of this preliminary investigation for the community stood at about $10kWhm^{-2}$ per day. In comparison with NASA (2002) report, this location promises to fall within the high insolation zone of the globe as can be seen in the insolation scale of Fig. 1. Therefore this study should be given more attention.

Conclusion

The preliminary investigation of the average daily insolation in Ihite Uboma Local Government Area of Imo State has been determined at a figure of about $10kWhm^{-2}$ per day. This was done using the correlation between solar insolation and the solar resistance of a cadmium sulphide photoresistor cell. Measurement was done for many days. The solar insolation of a given location is usually a useful figure of merit when sites for solar projects are sought. In comparison to NASA (2002) report, the result of this preliminary investigation suggests that Ihite Uboma as a Local Government Area in Imo State of Nigeria belongs to the high radiation zone of the globe and so can support solar energy projects. This study is informative and should therefore be given elaborate attention.

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