DEVELOPMENT OF A LOW-COST SOLAR PYRANOMETER

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ABSTRACT

Effective solar projects require effective solar data collection, however with the high cost of pyranometers in the market, there arose the need to construct a low-cost device for the purpose of solar radiation measurements. A device was thus developed in the University of Port Harcourt, River's state, Nigeria by utilizing a photodiode, a thermistor, a lcd among other readily available components. Using a reference pyranometer for calibration, the device was able to deliver a mean global solar radiation value of 16.00MJ/m2/day, while the maximum value obtained during the test period was 20.70MJ/m2/day. The performance of the locally developed device compares and competes favourably with what is available in the market.

Keywords: Solar, Photovoltaic, Pyranometer, Irradiance, Calibration, Measurement

1. INTRODUCTION

With continuous degradation and harm caused the climate due to conventional global energy sources which is predominantly from fossils, there is need to deviate to renewable energy sources such as abundantly available solar energy Ayvazoğluyüksel & Filik (2018). Accumulated annual solar energy in the earth is said to be about 516 times greater than reserves of oil and about 157 times higher than reserves of coal deposits globally Nordell (2003). This implies that apart from being a friendly source of energy, solar energy is also heavily abundantly available. Nigeria, though located in the world's solar belt and having sunshine that averages 6.25hours per day which is almost 5.25kWhm^{-2} per day of solar irradiance Energy Access and Energy Transition in Nigeria: The Crucial Role of off-Grid Solar—Oolu Solar (2023), still lags behind in proper utilization of this potential. Though several attempts have been made to implement solar powered projects in parts of the country, especially in rural areas for the purpose of water supply, power supply among others through the utilization of photovoltaics (PV) Oseni (2012), these projects almost always fail or do not fulfill their target or purposes. Among several reasons like, maintenance, funding, and lack of skilled personel to manage these projects Abdullahi et al. (2017), lies the fact that proper irradiance data is not collected from the location which will aid planning for capacity and storage considerations before such projects are sited. In this research, a low cost solar pyranometer for the purpose of collection solar irradiance data is being constructed and calibrated for use. Photovoltaic systems rely of solar radiation data at a particular site for the purpose of design and planning. Solar Irradiance is the measure of the power density of sunlight or the total power from a radiant source falling on a unit area Ibrahim et al. (2019)

2. MATERIALS AND METHODS

The materials used for the construction are as listed in Table 1

Table 1

Table 1 Materials Used

S. No.	Components
1	Photodiode
2	Microcontroller
3	Liquid Crystal Display (LCD)
4	Thermistor
5	Operational Amplifier.
7	Resistor
8	Copper strip (Vero) board
9	DIP IC socket
11	Plastic Casing
12	Teflon Cover
13	Plastic Casing
14	Digital Multimeter
15	Batteries (9V DC)

2.1. SCHEMATIC CIRCUIT DIAGRAM

The schematic for the pyranometer circuit was developed using Proteus VSM Professional Figure 1

Figure 1

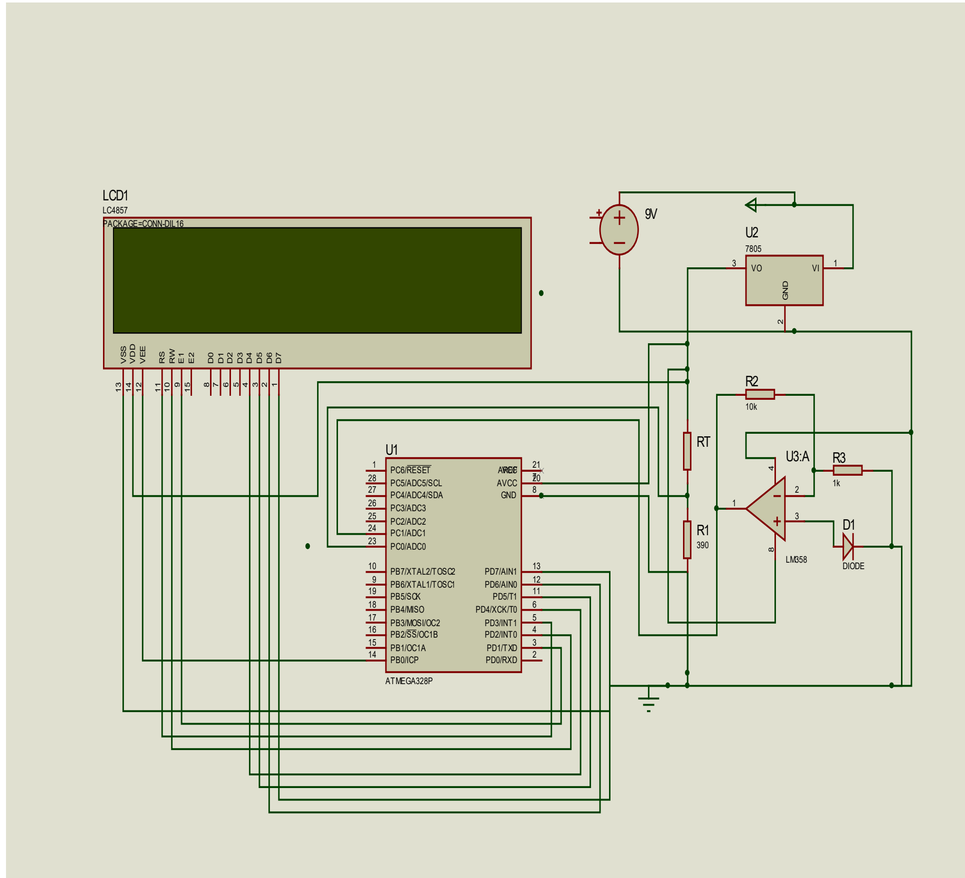

Figure 1 Pyranometer Schematic (Drawn with Proteus 6.0 Workbench)

2.2. CONSTRUCTION

The main steps taken during the construction of pyranometer are outlined below:

1) With the aid of the schematic circuit diagram, components were inserted onto a copper strip board (veroboard) and soldered, Figure 2. The photodiode and thermistor were soldered in such a way that they are accessible from within a casing.
2) Soldered connections were tested for shorts/open circuit using continuity function of a test digital multimeter.
3) A plastic casing providing a suitable circular opening on top for placement of Teflon diffuser over photodiode was fabricated and used which also had opening for the thermal sensor as seen in Figure 3.

Figure 2

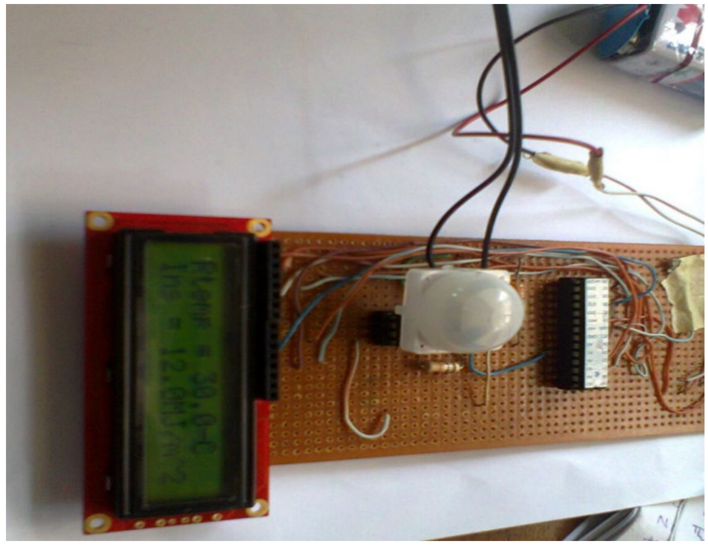

Figure 2 Internal Circuit with Components Soldered to Veroboard

Figure 3

Figure 3 Fabricated Plastic Casing for Pyranometer

2.3. TEST AND CALIBRATION PROCEDURES

Calibration was done based on Angstrom type model developed by Chukwuemeka and Nnabuchi (2009). This model is suitable for estimating the monthly average daily insolation in any given location in Nigeria such as Port Harcourt. The steps taken for calibration are outlined below:

1) Place Pyranometer on level horizontal surface
2) Take 4 set of hourly readings of the temperatures on LCD and test Digital multimeter. Also read off insolation ADC value of pyranometer at the measured temperatures.
3) Take the average insolation ADC values for temperatures greater than 27°C.
4) Repeat these readings for selected days for each week of the month and take the grand average. This value should be equivalent to the expected total daily mean.

3. RESULTS AND DISCUSSIONS

Using the model derived from Chukwuemeka and Nnabuchi (2009), the values of the daily global solar radiation (INS) on a horizontal surface calculated for the month of October, 2022, for Port Harcourt (late 4.85° N, long 7.02°E, and altitude 19.55m), Nigeria is as shown in Table 2 and plotted in Figure 4 using Matlab software program. The highest global solar radiation value of 20.70 MJ/m²/day was obtained on the 14th and 25th day, while the lowest value of 7.60 MJ/m²/day was obtained on the 24th day. The graph showed that the global solar radiation was on the decrease between the 10th and 12th day, and the 14th and 17th days. This may be attributed to the reduction of solar radiation due to cloud cover. The mean global solar radiation obtained for the month of October 2022 at Port Harcourt is 16.00MJ/m²/day. The temperature difference (Figure 5) is also highest on the 22nd day and lowest on the 17th day.

Table 2

Table 2 Temperature Measurement and Solar Radiation at Port Harcourt				
DAY OCT 2022	INS (MJ/M²/DAY)	TMAX(°C)	TMIN(°C)	Td(°C)
8	11.40	27.10	25.10	2.00
9	19.00	26.80	24.90	1.90
	18.90	27.50	25.30	2.20
11	10.00	26.70	25.00	1.70
12	17.00	25.80	24.90	0.90
13	16.50	26.60	25.10	1.50
14	20.70	26.80	25.00	1.80
15	14.50	27.20	26.20	1.00
16	14.90	27.00	25.30	1.70
17	13.50	26.80	26.40	0.40
18	18.40	27.20	26.10	1.10
19	16.00	27.40	25.10	2.30
20	16.60	26.80	25.30	1.50
21	14.10	27.20	25.40	1.80
22	20.10	28.10	25.30	2.80
23	15.00	26.90	25.30	1.60
24	7.60	26.20	25.30	0.90
25	20.70	27.30	25.40	1.90
26	20.30	27.30	25.30	2.00
27	14.70	26.60	25.20	1.40

Mean Global Solar Radiation (in Port Harcourt for the month of October 2012) =

(11.40+19.00+18.90+10.00+17.00+16.50+20.70+14.50+14.90+13.50+18.40+ 16.00+16.60+14.10+20.10+15.00+7.60+20.70+20.30+14.70)/20= 15.995=16.00 **MJ/M²/DAY**

Figure 4

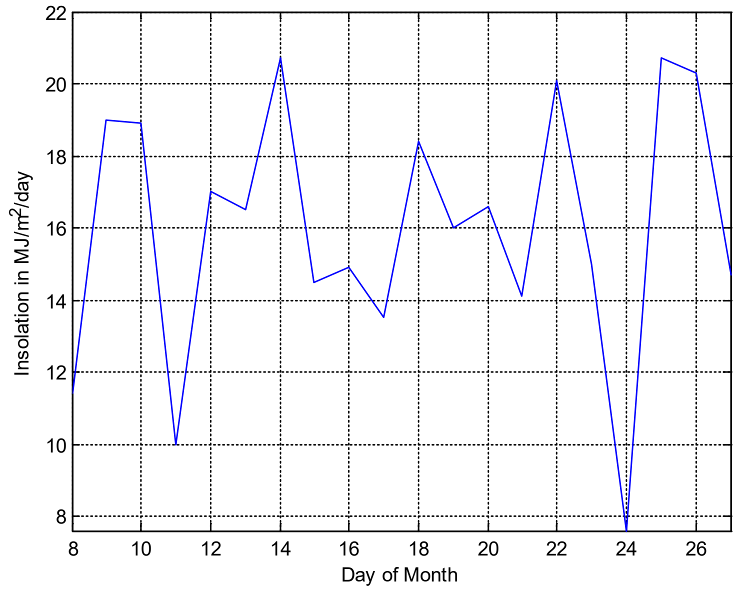

Figure 4 Line Plots of Global Solar Radiation from October 8th to 27th, at Port Harcourt (as Plotted by Mathlab)

Figure 5

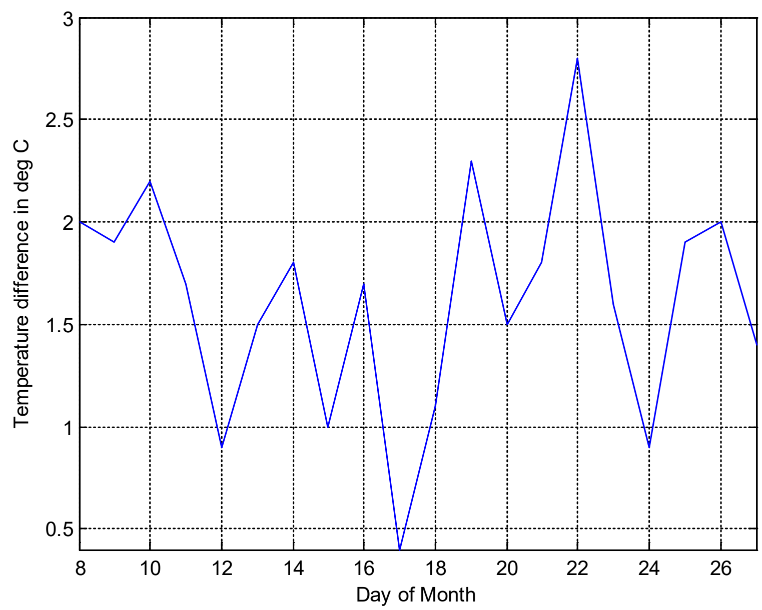

Figure 5 Line Plots of Temperature difference from October 8th to 27th 2022 at Port Harcourt (as Plotted by Mathlab)

4. CONCLUSIONS AND RECOMMENDATIONS

Utilizing locally available components and materials has made the construction process of developing a pyranometer affordable and straightforward. This does not however take away the fact that a proper understanding of the principles are of great importance. The Pyranometer was constructed and further calibrated against the Chukwuemeka and Nnabuchi (2009) model which is of a reputable quality with a calibration constant of 5230 ± 0.024mJm^{-2}. The developed Pyranometer was studied and tested under live environmental conditions in the Port Harcourt, Rivers state environs of Nigeria. The yielded results were found to have competed favourably with the referenced standard.

It is recommended that longer periods of up to a year be used to take measurements to ascertain more accuracy for such devices.

CONFLICT OF INTERESTS

None.

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