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DETERMINATION OF OPTIMAL FOCAL POINT OF A CONICAL SOLAR CONCENTRATOR USING ARDUINO AND OPTICAL SENSOR

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Abstract

Sunlight is a renewable energy source which can be converted into other form of energy by solar collectors. Concentrating solar powerconvert sunlight to a heat which then convert it into mechanical energy.The aim of this work is to determine the optimal focal point of the conical solar concentrator. Determining the focal point of the conical solar for green energy harvesting systemenhance performance and efficiency. The determination of focal point for optimal thermal radiation, performance analysis of a solar conical concentrator was conducted using Arduino microcontroller and GY-302 BH1750FVI optical sensor. Focal point on system was tested on different hours of the day. The analysis results of the system according to the varying distances showed that the maximum thermal radiation collecting point is few inches above the lower opening of the conical device. Thermal radiation rate increase as the optical sensor moves above the lower opening of conical. It was advisable to determine the maximum focal point in order to achieve the maximum power and efficiency. The focal point on the system is at 6 inches above the lower opening.

Keywords: maximum focal point, conical solar concentrator, Arduino, optical GY-302 BH1750FVI sensor.

1. INTRODUCTION

Non-renewable fuels, such as oil, natural gas, and nuclear energy, are used as main sources of energy. In recent years, due to increasing number of vehicles and manufacturing industries has contributed to environmental pollution, global warming, and resource reduction. Due to these problems, it has forced to improve technologies and increasing the efficiency on the renewable energy sources. Renewable energy system is growing very fast, moreover, technologies brings cost down and starts to deliver on the assurance of a green energy harvesting in future. Solar energy being one of the renewable energy sources,has become most energy sources used especially in the remote area. It has received more attention and increased applications such as cooking and lighting. This source of energy has many advantages, it offer the benefit of lower emissions of carbon and other types of pollution, endless, and plentiful but has minimal negative environmental. Currently, solar energy is one of the largest and cheapest source of energy. For the last few decades technologist have constantly worked on the solar energy in domestic use devices such as solar concentrators for cooking and heating. In general, a research is being done on a specific solar concentrator devices that can deliver higher solar radiation than a normal flat collectors. The conical solar concentrator system uses high reflective optical materials to achieve high thermal energy in order toconfine maximum energy at a focal point. The system consists of a conical shaped solar concentrator, solar energy sensor and Arduino microcontroller. The light ray incident in upper opening of the conical concentrator are reflectedback by walls, and the radiation is confined at one focal point where maximum rays converge. The solar sensor is used to determine the specific focal point where maximum radiation is confined to achieve high efficiency of the system. In this work, the optimal point was determined based on theoretical studies, which consider maximum focal point as maximum concentration point of the radiation. The objective of this study was to identify and determine the maximum focal point of rays inside conical concentrator to attain high collecting and efficiency solar harvesting device. The maximum solar radiation in the conical solar concentratorwas achieved by incidence angle of 45°, which agree with theoretical study.

2.1. MATERIALS AND METHODS

In this work, an Arduino-based, maximum optimal solar radiation focal point was investigated and determined,using Arduino and optical sensor the system was designed and constructed. Effect of the concentrator's incidence and reflected angles provides a suitable approach for high concentration of light rays solutions. To investigatethe maximum radiation concentration pointby incidence radiation and reflected radiation angles in the conical device's openings, the following design variables were defined and calculated. The evaluation of the maximum optimal focal point of importance, few parameters have to be considered before the procedure process, they are x_n , z_n and $\emptyset_n$ must be done iteratively, once θ_f, x_1 and $\emptyset_1$ are known.

x_n = the large and smaller diameters of the conical shape device

z_n = the distance between the two diameters of the conical shape device

$\emptyset n$ = the angle of incidence and reflection inside the conical shape device

The general expression for x_n and x_{n+1} after n reflections are:

$$z_n = \frac{x_n \cdot cos(\theta_f) \cdot cos(\emptyset + (2n-1)\theta_f)}{sin(\emptyset + 2n\theta_f)}$$

and

$$x_{n+1} = z_n \cdot [tan(\emptyset + (2n-1)\theta_f) - tan(\theta_f)]$$

The total depth of the ray inside conical device can be computed from $\sum_1^n z_n$ after n reflections.

The light ray's incident angle at the conical wall becomes narrower along the horizontal in each reflection. However, after repeated reflections depth will no longer be there into the conical device but light reflect back out of the conical opening whence it came from as incidence. Where the maximum number of reflections meet in the conical device for the maximum focal point, this occurs once the light ray is reflected slightly upwards from the bottom opening. Successive reflection will reflect and meet almost at common point upwards towards the conical opening.

To obtain a maximum focal point for the conical device by using the ratio of the incidence radiation at the conical opening where the light comes in and the outgoing radiation conical at the bottom that is the initial conical opening to the conical exit dimension$\frac{y_1}{y_n}$. This designs to define the functions.

$$f(n) = \frac{cos(\theta_f) \cdot cos(\emptyset + (2n-1)\theta_f)}{sin(\emptyset + 2n\theta_f)}$$

And

$$g(n) = \left[tan\left(\emptyset + (2n - 1)\theta_f\right) - tan\left(\theta_f\right)\right]$$

Here the factors multiplying the distances x_n and z_n respectively. The maximum ratio $\frac{x_1}{x_2}$ after n reflections can be expressed by eliminating z_n. This gives

$$\frac{x_1}{x_n} = j^{1-n}[f(1)f(2)\dots f(n-1)g(1)g(2)\dots g(n-1)]^{-1}$$

This gives the device maximum radiation of incidence radiation and outgoing radiation of conical at the initial conical opening and the conical exit opening$\frac{y_1}{y_n}$.

2.1. ARDUINO UNO BOARD

Arduino is an open source electronics prototyping platform based on flexible hardware and software. Arduino UNO is a board based on AT mega328 microcontroller. It consists of 14 digital input/output pins, six of them are analogue inputs, an interfacing bidirectional USB port for supporting transfer of data and programming with microcontroller, power connection jack, an ICSP header & a reset button. The Arduino software which is based on C programming language works in many platform such as Windows and Linux operating system. Therefore, the Arduino is better than many types of Microcontroller. The typical Arduino board is shown in the figure below.

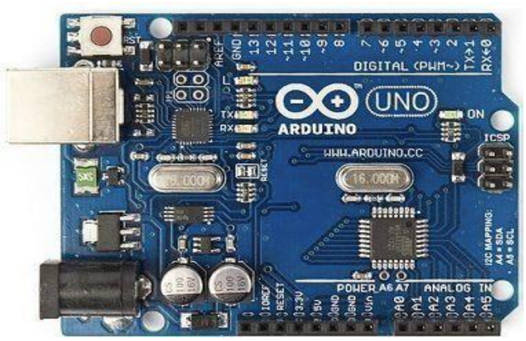


Figure 1. Arduino Uno Board

2.2 SOFTWARE PROGRAMMING

In this section of the work presents the software design of the Arduino microcontroller with software importance in the system procedure. The software used to interface hardware circuits, calculate the optimal focal point and testing the movement mechanism of the sensor. On this part, the movement of solar radiation sensor will be tested to determine the maximum focal point in the conical concentrator device to achieve the optimal point of solar radiation.

2.3. LIGHT INTENSITY SENSOR GY-302 BH1750FVI

The light intensity sensor used in this work is the GY-302 BH1750 with an output of lux/meter, but the measurement results will be converted to W/m2 (The LUX meter is used to measure visible part of the incident solar radiation. multiply lux to 0.0079 which give you value of w/m2). This light sensor GY-302 BH1750 is capable to measure the light intensity in the range from 1 to 65, 535 Lux. It communicate with microcontroller using I2C communication, that help communication with microcontrollers, this sensor only communicate with 2 pins, that is an SDA data pin (serial data) and SCL clock pin (serial clock line) and power pins (VCC and GND).The typical light Intensity Sensor GY-302 BH1750 is shown in the figure below.

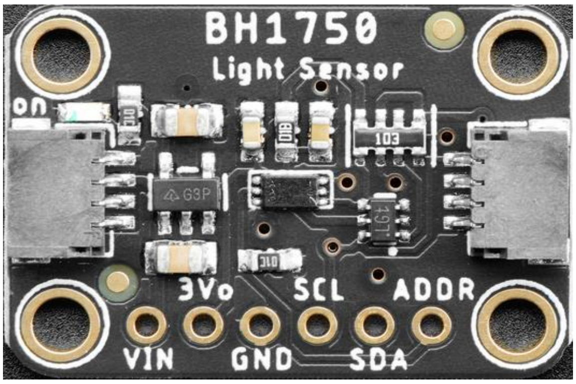


Figure. 2. Intensity Sensor GY-302 BH1750

2.4.KY-008 LASER TRANSMITTER MODULE

KY-008 Laser Transmitter Module is capable to emit powerful focused beam of visible red light. The operating voltage is 3-5 V and 40mA. This KY-008 Laser Transmitter Module can be connected direct to Arduino since Arduino pins can supply 40mA, if more than this current is required, laser driver is needed otherwise Arduino will be damaged.

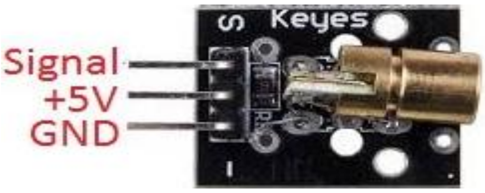
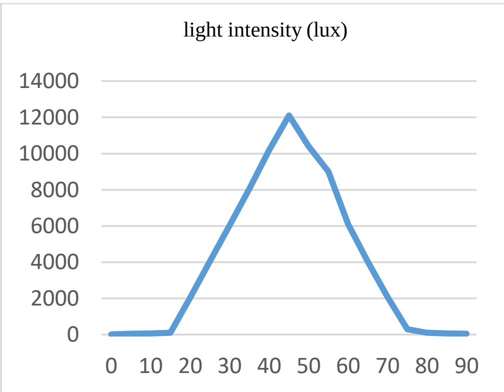


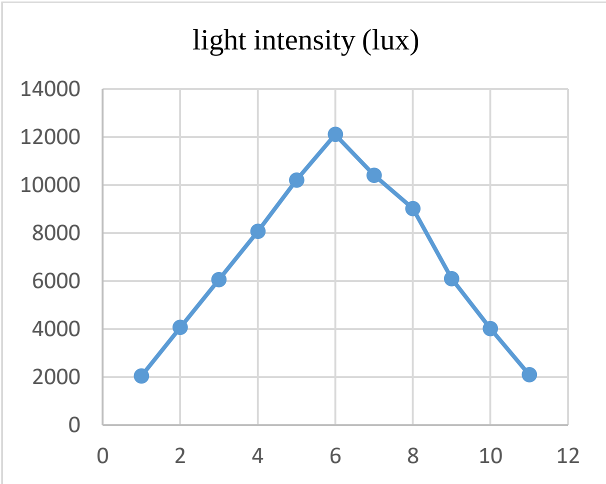
Figure. 3. KY-008 Laser Transmitter Module

Table 1. Laser Intensity (lux) Output at different angle of incident rays of the solar radiation

Angle(ϕ)	light intensity (lux)
0	20
5	50
10	70
15	100
20	2040
25	4060
30	6050
35	8060
40	10200
45	12100
50	10400
55	9010
60	6090
65	4010
70	2090
75	300
80	110
85	72
90	48



length (cm)	light intensity (lux)
1	2040
2	4060
3	6050
4	8060
5	10200
6	12100
7	10400
8	9010
9	6090
10	4010
11	2090



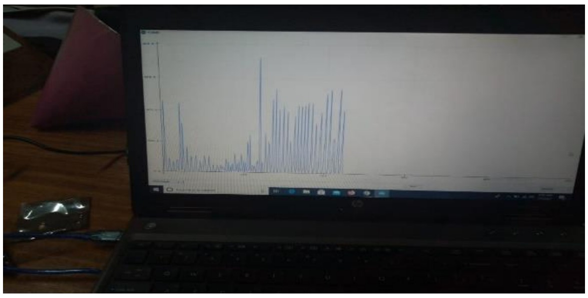


Figure. 4. Light intensity in from optical sensor

4. CONCLUSION

This proposed solar system is capable to determine the maximum optimal focal point in a solar conical solar concentrator for harvesting solar radiation. The power system trap and confine the sunlight intensity into one focal point. The aim of this project is to help those who use solar energy in their home for consumption as well as big size of solar system. The Arduino microcontroller based system to determine the maximum focal point of solar radiation in conical solar concentrator system. In order to determine the optimal focal point of the system, an experiment was done by moving sensor up, down or either side way inside the conical shaped solar concentrator device. The sensor operate properly when it is 6 inches above the conical lower opening. This system, the optimal solar radiation focal point willbe a game changer to our society by saving more, because it only use solar radiation and it does not have any pollution. The sensor is used to detect the optimal power focal point.

FUTURE IMPROVEMENTS

A. Automatic system can be integrated to track the sun movement, more sensors and motors to provide a better efficiency and accuracy.

B. If extra power is generated in the system,this energy will be used to charge battery for later consumption in case the solar radiation is low.This will help to keeps the system running.

C. Wi-Fi Module ESP8266 can be incorporated in the system together with internet connection for remote monitoring and controlling.

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