# Design and Development of Solar Insolation Simulator

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**Abstract:** ***To get the desired atmosphere for laboratory work is a difficult job for researchers. Specially, it is very much unreliable to get the required solar irradiance directly from the Sun. To solve this issue, a solar insolation simulator is designed and fabricated, through which the insolation can be easily controlled with the help of Arduino based system. In this simulator, solar energy is simulated using halogen bulbs, which provide the necessary insolation. The light dependent resistor (LDR) connected to the Arduino measures the amount of solar insolation falling on the solar PV module. A fan is used to extract out the access heat generated by the bulb.***

**Keywords:** Arduino; Solar Insolation; Solar Energy; Solar Insolation Simulator; PV Module.


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## 1. Introduction

The Sun is the major source of renewable energy. It provides living things energy to do day-to-day activities to survive. Human beings have also learned to harvest that energy to produce electricity [1]. The Sun's rays fall on the photovoltaic (PV) panel and this in turn, leads to electricity formation [2]. The PV panels are made of semiconducting materials, which reacts to light. When light falls on then electrons and holes get excited. This excitation causes a potential gradient to form and electricity is obtained [3]. But at times, it becomes a very unreliable source of energy when research work has to be done. Many external and internal factors affect electricity production [4]. They can cause damage to the panels and decrease the production level. The external factors can be dust or shade [5]. Temperature also plays a role in the output of the PV panels. Increase or decrease in the temperature in which the panel is kept changes the output indirectly [6]. The external or even internal temperature increase can result in increased recombination rates decrease the performance of the PV cell [7].

The MPP (Maximum Power Point) is very important if we want to obtain a good electrical output. But, it changes a lot throughout the day [8]. Even if tracking devices are used to assure a maximum output, the full potential of the PV panel is never utilized, giving a maximum efficiency of 25% - 30% [9].

The PV module combinations are also very important to obtain maximum output from the PV panels [10]. PV modules cannot give a maximum output if the PV panels cannot utilize their full potential. So, an insolation simulator can be very useful. This simulator mimics the Sun's rays and the amount of energy the Sun provides to a panel. The irradiance levels are changed according to the needs of the person using the simulator and the data needed is collected.

The data obtained from such experiments in a controlled environment will be free from external factors. The factors that affect the data will be as needed by the one performing the experiment. This data can be useful in conducting research on the solar PV plates. This research can help in increasing the efficiency (up to 40%-50%) of the PV plates so that more electricity can be produced and less loss will be incurred. Another good effect of the research conducted will help in reducing the carbon footprint of a nation at a much faster rate than in the present scenario.

## 2. Setup and Working of the Simulator

Figure 1 shows the sequence in which the setup is going to work.

Figure 2 shows the setup of the Simulator and the components that are going to be a part of the Simulator.

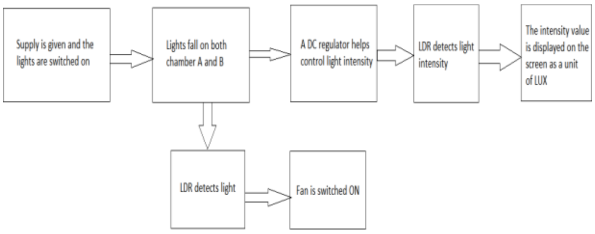


**Figure 1:** Block Diagram of the whole setup

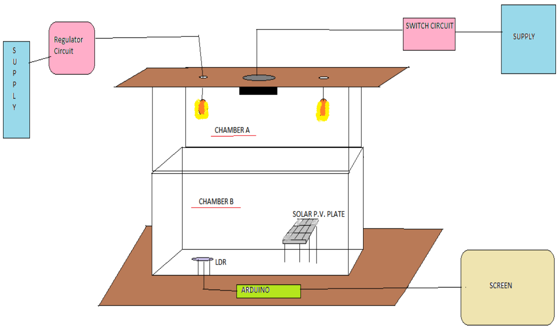


**Figure 2:** The Setup of the Simulator

### 2.1 Working of the Simulator

The following points show the components and the working of the Setup:

- The Setup consists of two separate chambers. The upper chamber is A while the lower chamber is B.
- There are bulbs and fan in chamber A. A light detector and solar plate are present in chamber B.
- Circuits are used to control the light intensity of the bulbs and the switching on/off of the fan.
- The light detector measures the light intensity reaching the solar plate.
- The circuit to control the light intensity uses an AC-DC converter (an adapter), a voltage regulator circuit and a halogen bulb. Here two bulbs are used.
- Switching on/off of a fan is done using a circuit that comprises of a transistor, a resistor, an LDR and the fan. The source for this circuit is also a DC source.
- The light intensity is measured using a circuit with an LDR, Arduino, a 10K resistor and a screen to take the readings.
- The light falls on the LDR and this is recorded on the Screen.
- Any change in the light intensity is done with the help of the light intensity control circuit.
- This change is simultaneously recorded on the Screen.
- The heat that is produced due to the light sources is expelled using the Fan circuit in chamber A.

## 3. Circuit Used

There are three main circuits that make the entire Setup.

### 3.1 Block Diagrams

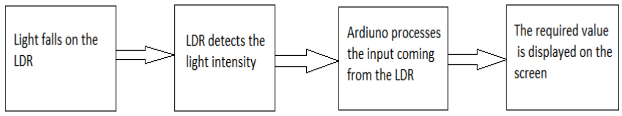


**Figure 3:** Light detection and value obtaining block diagram

This block diagram shows us the part of the circuit that will help in the measurement of the light intensity, i.e., the irradiance level.

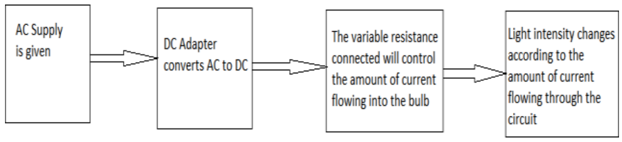


**Figure 4:** Light intensity control block diagram

This block diagram shows us the part of the circuit that will control the light intensity, i.e., the irradiance level.

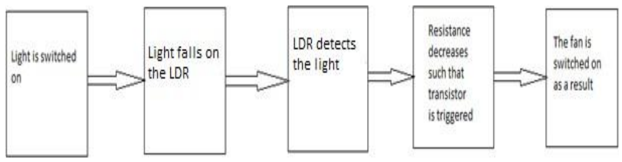


**Figure 5:** Fan switch control block diagram

This block diagram shows us the part of the circuit it that will switch on the fan when light is switched on.

### 3.2 Circuit Diagrams

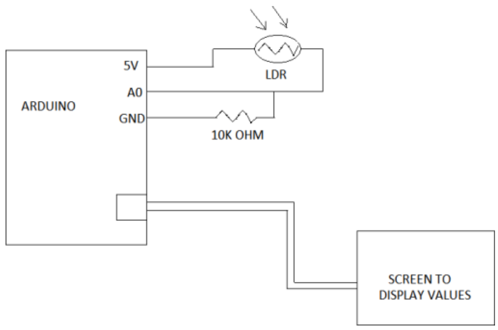


**Figure 6:** Light detection and value obtaining circuit diagram

This circuit diagram shows us the part of the circuit that will help in the measurement of the light intensity, i.e., the irradiance level. Here, Arduino is used to collect the data and convert the values coming from the LDR to LUX, which is the unit of light.

### 3.3 Arduino Program

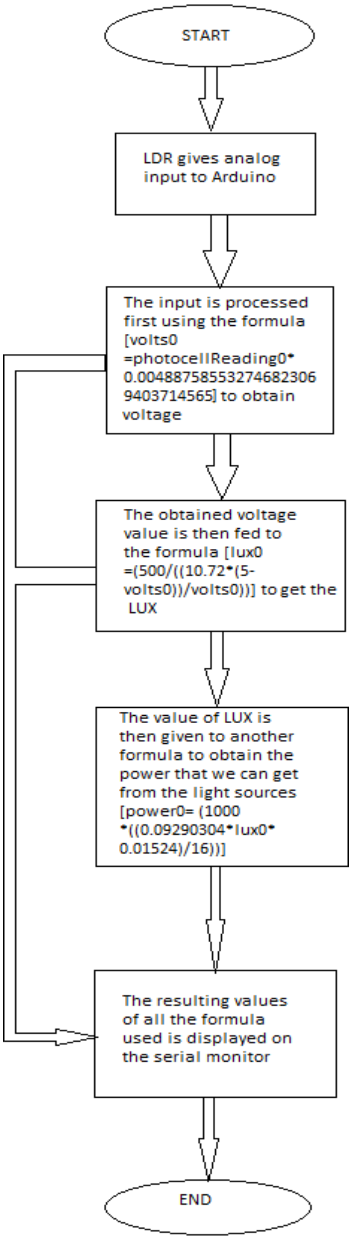


**Figure 9:** Flow Chart of the program used

The above flowchart shows how the program is going to work. Using this program, firstly, the LDR value is obtained. This value is then processed by the Arduino with the help of a formula
volts0 = (photo cell Reading 0) * 0.0048875855327468230694037145651
which converts the output of the LDR which is in voltage to a digital value. It is then processed using another formula
lux0 = 500 / [{10.72*(5-volts0)}/volts0]
which converts the digital value into the required value which is LUX. This value is then converted to power using another formula power0=[1000*{(0.09290304*lux0*0.01524)/16}]

All these values of voltage, LUX and power are then displayed on the serial monitor (Screen) of the Arduino application.

## 4. Results and Analysis

After working with the Simulator, data were obtained. When the light intensity changed, the LDR resistance also changes along with it. The increase or decrease in light intensity increases or decreases the LDR resistance accordingly.

This change in the resistance is taken into account. The resistance value is converted to the appropriate required value of the intensity of light. This intensity is measured in the unit LUX.

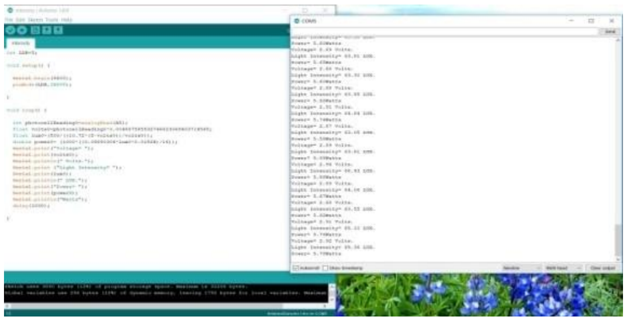

**Figure 10:** Data obtained from the Simulator

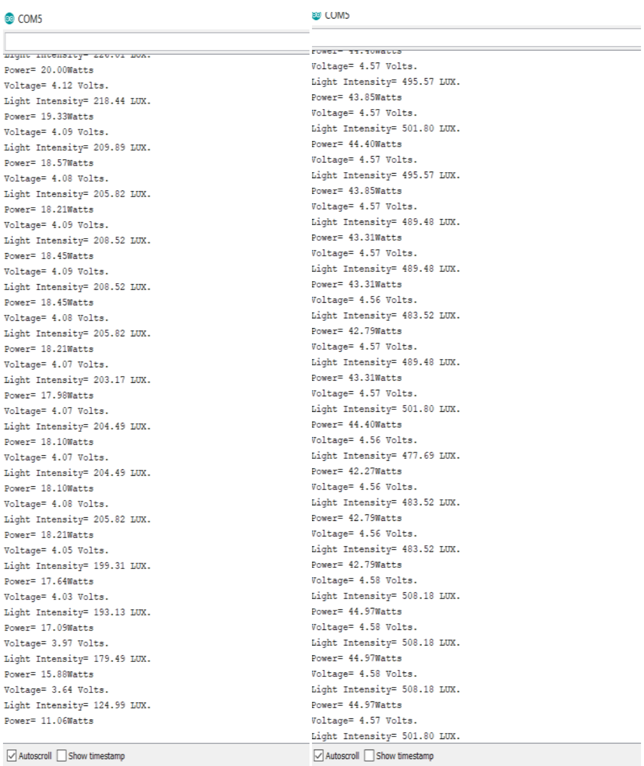


**Figure 11:** Data obtained

The analysis of the data shows that the light in the Simulator is similar to the light of the Sun. This also shows that it is completely fine to use it to perform experiments to research on PV cell development.

**Table 1:** The LUX and the Power obtained

| Obs. No | Light Source1 | Light Source2 | LUX Irradiance |
|---|---|---|---|
| | P | P | |
| | (Watts) | (Watts) | |
| 1 | 40.946 | 38.76 | 608.01 |
| 2 | 40.12 | 37.392 | 598.24 |
| 3 | 39.294 | 34.77 | 508.32 |
| 4 | 31.86 | 21.204 | 398.33 |
| 5 | 26.196 | 23.94 | 435.02 |
| 6 | 23.718 | 25.194 | 352.13 |
| 7 | 16.284 | 39.102 | 278.55 |
| 8 | 12.272 | 10.716 | 77.46 |
| 9 | 10.974 | 22.002 | 87.99 |
| 10 | 7.67 | 10.146 | 51.67 |

This table gives us the following graph:

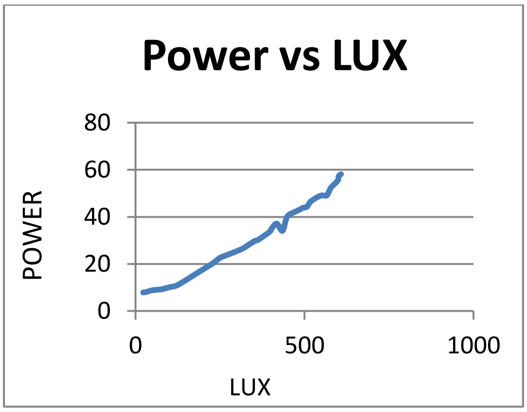


**Figure 12:** Graph indicates that the power increases as the LUX increases

Another table shows how the change in the intensity of light is similar to how natural light changes and the light intensity measured is also similar in values:

**Table 2:** Difference in the input power and the intensity obtained

| Obs. No. | LUX | Power (W) |
|---|---|---|
| 1 | 608.01 | 58.09 |
| 2 | 601.25 | 57.23 |
| 3 | 598.24 | 55.33 |
| 4 | 578.01 | 52.3 |
| 5 | 566 | 49.1 |
| 6 | 548.09 | 48.99 |
| 7 | 520.11 | 46.7 |
| 8 | 508.32 | 44.4 |
| 9 | 501.8 | 43.98 |
| 10 | 495.57 | 43.85 |
| 11 | 489.48 | 43.31 |
| 12 | 473.23 | 42.19 |
| 13 | 449.06 | 40.1 |
| 14 | 435.02 | 34.07 |
| 15 | 418.03 | 37.12 |
| 16 | 402.27 | 34.92 |
| 17 | 398.33 | 33.81 |
| 18 | 363.08 | 30.25 |
| 19 | 352.13 | 29.74 |
| 20 | 323.04 | 27.01 |
| 21 | 311.79 | 26.16 |
| 22 | 278.55 | 24.21 |
| 23 | 254.02 | 22.89 |
| 24 | 243.18 | 21.9 |
| 25 | 226.19 | 20 |
| 26 | 218.44 | 19.33 |
| 27 | 209.89 | 18.57 |
| 28 | 203.17 | 17.98 |
| 29 | 199.31 | 17.64 |
| 30 | 193.13 | 17.09 |
| 31 | 179.49 | 15.88 |
| 32 | 124.99 | 11.06 |
| 33 | 103.24 | 10.22 |
| 34 | 87.99 | 9.67 |
| 35 | 77.46 | 9.24 |
| 36 | 51.67 | 8.88 |
| 37 | 30.91 | 8.1 |
| 38 | 22.78 | 7.92 |

In this table, the power supplied to the light sources (i.e. the two bulbs) gives different intensities of lights. These differences in the supplied power can be such that both sources can be high giving the high intensity of light. If any one of the sources is high while the other is low, we get a medium intensity and if both sources are low a low light intensity is obtained.

## 5. Conclusion

In a concluding note, it is found that this Simulator is an excellent alternative to obtaining the data that can be used for research in order to improve upon the existing PV cells. This improvement can further increase the efficiency of the PV panels.

This setup can also be used by amateurs and professionals alike. So, anyone who wants to have a hassle-free environment can use it. Manufacturers can also use it wherever they may be situated and even when the Sun is not present.

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