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Test Bench Solar Power Measurement

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Abstract: **Solar energy is increasingly being used in residential, commercial, and industrial settings. Solar energy is a kind of renewable energy derived from the sun's heat. India will have 34,627 MW of solar power built by 2020. An experimental system for measuring solar panel power was established in this research. This current has been used to monitor voltage and light intensity. The sun has a declination angle of +23.5 degrees and a declination angle of -23.5 degrees with respect to the earth. An incandescent bulb light is used to mimic the sun, with the angles carefully adjusted. This diagram shows the variance in solar power output at the load side, as well as the power and load resistance.**

An incandescent light bulb is used to create light intensity for the solar panel. Using a voltage regulator, the light intensity was varied. Voltmeter and ammeter measurements are used to calculate the power. Solar energy is used to mimic the properties of solar panels' output power. To move from east to west, the model of the sun was turned into an incandescent bulb light and set on the circular iron track. With the aid of a D.C speed regulator, you may adjust the bulb's position and light intensity. The solar panel is positioned such that it may easily move to various orientations. Calculate the power with the use of a voltmeter and an ammeter. Resistance is compared to power, which is the only source of energy. The important intention of this paper is to ascertain that the most electricity output occurs when a resistor bank is used as a load.

Index terms: **Solar panel, light intensity, resistor, voltage, current, power, incandescent bulb light.**

I. Introduction

Solar power is an alternative source which is available from the sun. Electrical power is generated from solar panel output D.C terminals. Solar energy is renewable energy. Most of the power systems generate power from resources such as coal, water etc.

Solar energy produced from sun rays is an inexhaustible source of convenient energy. Solar energy is electromagnetic energy. The sun rays falling on the earth's surface create angles. The photovoltaic effect principle is used to produce electricity. Solar energy depends on the sun. There is a need for monitoring and measurement of solar energy. For thousands of years, the sun has generated energy. For thousands of years, the sun has been a source of energy [1]. The sun's beams that reach the earth's surface are known as solar energy. Solar energy is unique source of energy, and it can be exploited into useful form by different ways such as:

1. Photosynthesis converts sunlight directly into fuel.
2. Photovoltaic panels convert sunlight directly into energy (PV).
3. By direct conversion into electricity through thermal electric power systems. In this system, the solar radiation is converted into heat energy which is further converted into mechanical energy and then into electrical energy.

• Solar power generation is increasing day by day. Solar energy is a renewable source of energy that is generated by the sun as shown in figure 1.

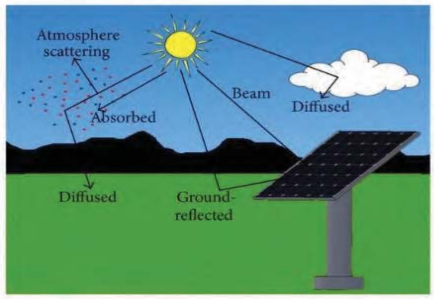

Figure 1. Sun rays on the earth surface

• Atmospheric scattering is a natural phenomenon that can be described as the result of the interaction between sunlight and particles in the atmosphere.

• Diffuse radiation is solar radiation that reaches the earth's surface after being dispersed by molecules in the atmosphere from the direct sun beam.

• Beam radiation is solar energy that has not been dispersed and is directed in the same direction as the relative geometric location between the sun and the earth.

• Solar radiation near to the earth surface can be measured by following instruments: Pyrheliometer, Radiometer, photometer, Ground radio meter, Microwave radiometer, Multifilter rotating shadow band radiometer, Narrow field of view zenith radiometer etc.

II. Basics of Solar System

A. Solar Power

Sun-oriented power is the conversion of energy from daylight into electricity, either directly using photovoltaics (PV), indirectly via focused sun-based force, or a combination of the two. Sun-powered global positioning frameworks and concentrated sun-based force frameworks employ focal points or reflections to focus a large amount of sunshine onto a small pillar. Photovoltaic cells use the photovoltaic effect to convert light into an electric current. Solar energy is an extremely significant source of energy for

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the planet and its people. There is no life if the sun isn't shining. Solar energy is the source of all biomass on the planet's surface, as well as fossil fuels. Winds are created by solar energy, which evaporates water and causes rain, waves, and ocean thermal power [2].

B. Solar Energy

Energy is the capacity of an item to do some measure of work. Energy is accessible in positive systems like motor electricity, predicted energy. Sunlight primarily based power is the electricity of the solar. Consistently the earth gets the strength at once from the solar. Utilizing some logical strategies, sunlight-primarily based strength can be modified over in a few beneficial kind of electricity.

For example, we are able to alternate over into other structures like warmth electricity, dynamic energy, capacity energy and so forth Sun based power arrives at the earth as waves which in sunlight. One meter square area of the ecosystem 1.4 KW/m^2 intensity created. The sun-oriented energy diminished because of gas particles, water fumes, dust particles and appearance in air. The force of sun powered energy arriving at the earth is around 1 KW/m^2.Hence this energy is used to warm water and produce the power. Sunlight based energy is changed over into electrical energy by utilizing photovoltaic cells which are made by utilizing silicon.

C. Solar Constant

The heat is created by many types of fusion reactions, resulting in a vast sphere of very hot gases. Its diameter is 1.39×10^6 kilometers, whereas the earth's is 1.27×10^4 kilometers. Although the sun is huge, it only subtends an angle of 32 minutes at the earth's surface, therefore the average distance between them is 1.5×10^8 km. This is due to the fact that it is also located at a considerable distance. As a result, the earth's beam radiation from the sun is almost parallel. The sun's brightness ranges from its core to its periphery. For engineering calculations, however, it is common to assume that the brightness of the solar disc is homogeneous throughout. The energy emitted by the sun seems to be nearly comparable to that emitted by a black surface at 5262 degrees K when seen from Earth.

III. PRINCIPLE OF CONVERSION OF SOLAR RADIATION HEAT

The greenhouse effect is the basic method for heat conversion. Exotic plants may be grown in cold areas by making greater use of the available sunshine. Solar thermal generating is the most efficient technique to convert the energy in sunshine into heat. It includes the sun as a source of heat that is distributed to the ground. This heat is captured, concentrated with the help of solar collectors [3].

Components used in Solar Power Measurement:

A. Two Channel Relay Module

Figure 2. Two channel relay

Two channel transfer module is the module configuration to control two transfers in a basic manner and adaptable. It is viable with Arduino, the hand-off module associated with the assistance of jumpers as shown in figure 2. By utilizing transfer mounted on module two Arduino computerized input/yield pins, it is feasible to control motors, inductive burdens, and other devices. This two-channel hand-off module is utilized in homegrown tasks and in the space of mechanical technology papers.

Optocouplers are installed on the IN1 and IN2 lines of the module to guarantee galvanic protection between the transfer load and the control board that drives it. Associations Capacity of pins TTL advanced information for IN1 TTL computerized input IN2 Ground +5V Force (+5V) GND NO1 Keep the communication open on a regular basis. Normal contact (COM1) NC1 Normally closed contact 1 NO2 Normally open contact Normal contact (COM2) NC2 normally closes contact 2; Pin Capacity +5V power supply.

B. Incandescent Bulb Light

Energy conservation is changing into an addition of a priority. One objective is to utilise more energy-efficient lighting in reception areas, schools, companies, and public areas. This article will define essential concepts that should be used when discussing light weighting as well as different types of light bulbs.

- Watt (abbreviated W) is a unit that measures the rate at which energy (or power) is used in an electrical circuit, such as in the case of a light bulb as shown in figure 3.

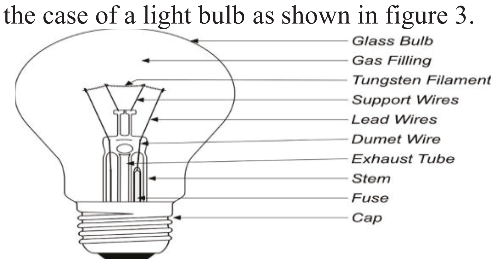

Figure 3. Incandescent bulb light

- Lumens square measures the unit of the number of sunshine (energy) as seen by the human eye that's given off by the sunshine bulb.
- One lumen covering a sector of one square metre is defined as one lux. To put it another way, a lux (light intensity) measurement informs you how many lumens are necessary for the realm to be light.

The incandescent lightweight bulb has had identical style for over a hundred years since Edison fictionalized it.

C. Dataset Description

Arduino mega microcontroller is associate degree open supply, computer onerous product and programming organization, activities, and a customer-specific facility that designs and manufactures single-board microcontroller units for use in sophisticated devices and intuitive goods that can detect and control things in the real world. The comes things sent as ASCII text file instrumentality and programming, which area unit approved below the wildebeest lesser overall population license (LGPL) or the wildebeest overall population license (GPL), allowing for the grouping of Arduino sheets and the distribution of Arduino code to anybody.

Arduino board plans use a partner degree variety of central processor and regulators. The sheet area unit comes with a set of cutting-edge and basic data/output (I/O) sticks that may be connected to a variety of augmentation boards (shields) and circuits. On versions that are unit to boot, the sheets include progressive exchange connectors, including Universal Serial Bus (USB), which is used for stacking applications from PCs. The region unit of the microcontroller was altered in a routine manner utilizing features from the programming languages C and C++. In addition to employing standard compiler instrument chains, the Arduino comes with a partner degree integrated development environment (IDE) for dealing with language papers.

The Arduino began in 2003 as a programme for understudies at an association design institute in Ivrea, Italy, with the goal of providing the most cost-effective and straightforward techniques for kids and experts to choose contraptions that interact with their current condition employing sensors and actuators as shown in figure 4 and 5. conventional examples of such contraptions papered for novice experts to join essential robots, indoor controllers, and development identifiers. The name Arduino is derived from a tavern in Ivrea, Italy, where a number of the ventures' pioneers congregated. Arduino of Ivrea, the margrave of Ivrea's promenade and ruler of a European kingdom from 1002 to 1014, was the inspiration for the bar's name.

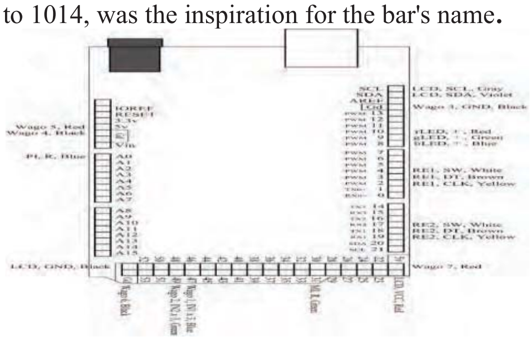

Figure 4. Arduino mega 2560 pin configuration

Figure 5. Arduino Mega 2560 layout

Arduino is basically a microcontroller which controls the relay functions. Arduino MEGA 2560 is used in this paper.

D. Power

The Arduino Mega area is often powered via a USB connection or an outside power supply. The power offer is mechanically selected. An associate degree AC-to-DC adapter(wall-mole) or battery will return external(non-USB) force. Connecting a pair of 1mm focus positive fittings to the board's force jack is a common way to associate the connection. Leads from a battery are often placed in the force connector's Ground and Vin pin connectors. The board will run on a six-to-twenty-volt external power supply. When supplied with less than 7V, however, the 5V pin may give less than 5 volts, making the board unsafe. If you use more than 12V, the voltage controller will overheat and cause damage to the board. There are seven to12 volts. The Mega 2560 is not constant as each single goes before the board.

The power pins are as per the following:

- VIN: While the Arduino board is using an external power supply, the data voltage to the Arduino board (rather than five volts from the USB association or different directed force source). This pin may be used to deliver voltage or to obtain voltage from a force jack.
- 5V: The controlled power allows the microcontroller and other board components to be handled in the same way they are used to. This might come from VIN through an on-board regulator or a purchase of a USB or other directed 5v supply.
- 3V3: The on-board controller has produced a 3.3 potential unit offer. 50 mA is the maximum current draw.
- GND: Ground pins.

It comprises 54 advanced info/yield pins, where 14 are PWM pins,16 pins are Analog inputs,6 equipment sequential ports. It controls the wheels forward and backward movements by using switches. It's also used for irradiation measurement using sensor LDR and used for relay operation.

E. Electrical device (Transformer)

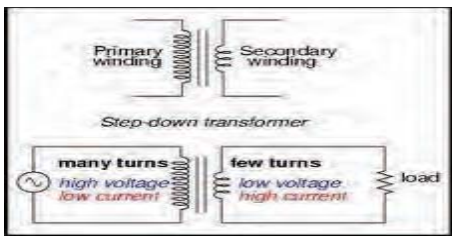

Figure 6. Transformer

- Transformer is a constant frequency device as shown in figure 6.
- Transformer is a constant power device.
- A transformer is a device that converts electromagnetic energy (Internal process).
- A complete transformer is not a device for energy conversion.
- It is a coupled circuit.
- Transformer is a constant flux device.

- More number of turns on the transformer side is called high voltage winding and lesser number of turns on the transformer side is called low voltage winding.
- Supply connected to the transformer called primary, load connected to the transformer so called secondary.
- A step-down transformer is used for converting high voltage to low voltage. Generally, 230 volts,50HZ A.C transformers are used [4].

F. Push Buttons

Press button is a switch which associates its terminal if it is squeezed. As the catch is delivered the terminal gets detached. Hence it is utilized to take contributions from users. This information can be high or low voltage that depends on that one terminal is associated with which source as shown in figure 7.

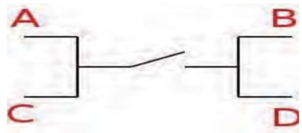

Figure 7. Schematic Diagram of Push Button

G. Light dependent resistor (LDR)

It is basically a photoconductivity device. A photoresistor, also known as a light dependent resistor LDR, is a passive component that reduces resistance in relation to the received luminance on the sensitive surface of the component. It works on the principle of voltage division. It has three terminals VCC (5 volts), Ground and voltage divider point(V) as shown in figure 8.

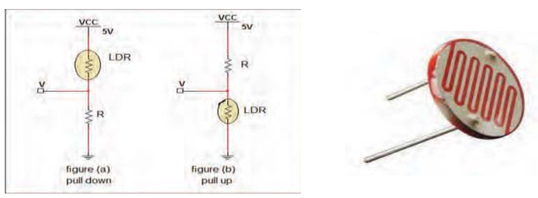

Figure 8. Light dependent resistor (LDR)

H. Solar Panel

A solar panel consists of a collection of solar cells. A solar battery is a collection of solar cells that are electrically linked on support structure. An electrical phenomenon module is a pre-assembled, solar-cell-connected assembly [5]. The solar battery will be utilized as part of a larger electrical grid system to generate and distribute power in commercial and residential settings as shown in figure 9 - 13.

Figure 9. Solar panel

A sun-oriented cell is a specific semiconductor gadget diode that changes over apparent light into direct current. Photovoltaic cells are an indispensable piece of sun based electric energy frameworks, which are turning into an inexorably significant option as wellsprings of utility force as shown in figure 10.

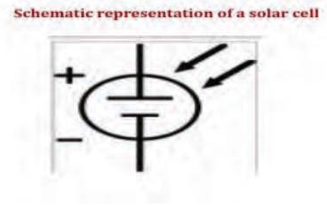

Figure 10. Simple representation of solar cell

I. Four Wheels

These wheels are rubber tires which have a rough surface to move the upper wooden board with the help of motor rotation. Four wheels, in this two Wheels Run by D.C motor which are supported to rotate another two wheels.

IV. Hardware Setup Operation and Measurement of Power

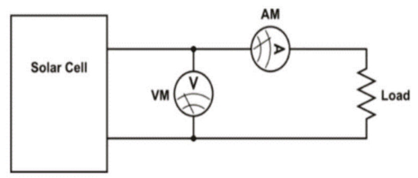

Figure 11: Solar panel connected to resistive load

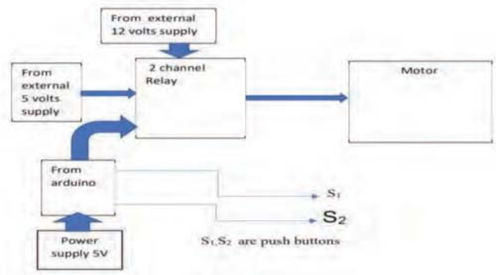

Figure 12. Block diagram for connection of Arduino, relay, motor, push buttons

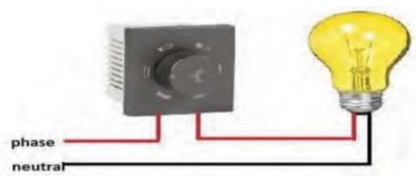

Figure 13. Incandescent bulb light intensity changed with the help of D.C speed regulator

Irradiance, a radiometric amount, measured in watts per square measure (W/m^2). The hardware setup is shown in figures 14 -20.

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Figure 14. Four wheels D.C motor

Figure 15. Solar panel and incandescent bulb setup

Figure 16. D.C regulator, load connection

Figure 17. Resistive load as per requirement

Figure 18. Two channel relay with Arduino snapshot

Figure 19. Hardware setup snapshot RPS, bulb at 90°

Figure 20. Snapshot of solar power measurement.

V. Procedure

- Connect the power connector to Arduino from CPU for 5V.
- A 5V D.C supply given to relay input.
- A 12V D.C supply taken from D C regulated power supply for motor input.
- A 230V A.C supply given to the Incandescent bulb through voltage regulator for varying light intensity.
- Connect required connection from Arduino,2 Channel Relay, Switches motors and main A.C supply.
- Dump the program into the Arduino.
- Switch ON all power supply.
- Set the solar panel at 0°.
- Place LDR at the solar panel for light intensity measurement.
- Move the incandescent bulb at various degrees from 15° to 90°.
- Connect the load across Solar output terminals.
- Measure the voltage and current by placing ammeter in series and voltmeter in parallel to the load and power is calculated from readings.
- Set the solar panel at 23.5°, -23.5° and move the incandescent bulb (high intensity only) at 90° and measure voltage, current and calculate the power.
- The graph shows the relationship between Resistance (R) and Power (P) [6 - 10].

VI. Experimental Results

A. Solar Panel at 0^0 Degree

(a). Incandescent bulb at 15° high light intensity

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TABLE I.
INCANDESCENT BULB AT 15 DEGREES HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (ohms)	Voltage(volts)	Current(mA)	Power(mW)
10	0.04	1.95	0.078
20	0.059	1.95	0.115
47	0.101	1.94	0.195
75	0.165	1.94	0.32
220	0.43	1.92	0.82
330	0.629	1.91	1.20
470	0.951	1.89	1.79
660	1.21	1.88	2.28

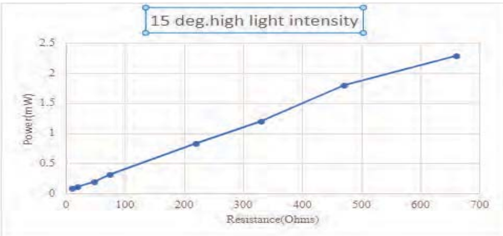

Figure 21(a). R versus P incandescent bulb at 15° high light intensity.

(b). Incandescent bulb at 15° less light intensity

TABLE II.
INCANDESCENT BULB AT 15 DEGREES LESS LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.033	1.67	0.052
20	0.049	1.64	0.08
47	0.084	1.63	0.13
75	0.13	1.63	0.22
220	0.35	1.62	0.58
330	0.53	1.61	0.85
470	0.80	1.6	1.28
660	1.05	1.61	1.67

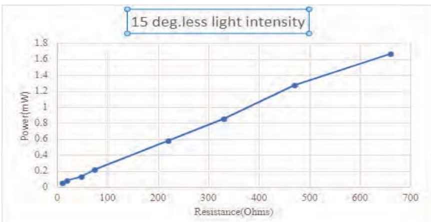

Figure 21(b). R versus P incandescent bulb at 15° less light intensity

(c) Incandescent bulb at 30° degrees less light intensity

TABLE III.
INCANDESCENT BULB AT 30 DEGREES LESS LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.05	2.34	0.127
20	0.071	2.34	0.166
47	0.121	2.34	0.463
75	0.198	2.34	0.463
220	0.521	2.33	1.21
330	0.765	2.32	1.77
470	1.144	2.27	2.59
660	1.492	2.28	3.4

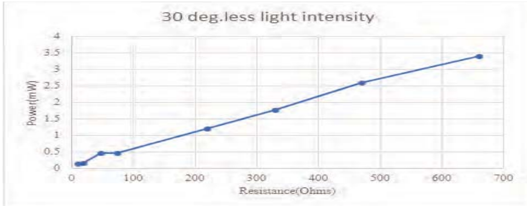

Figure 21 (c). R versus P incandescent bulb at 30° less light intensity

(d) Incandescent bulb at 30° degrees high light intensity

TABLE IV.
INCANDESCENT BULB AT 30 DEGREES HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance(ohms)	Voltage(volts)	Current(mA)	Power(mW)
10	0.111	4.42	0.49
20	0.135	4.41	0.595
47	0.23	4.4	1.012
75	0.370	4.39	1.624
220	0.967	4.34	4.19
330	1.42	4.31	6.12
470	2.2	4.25	9.46
660	2.73	4.20	11.47

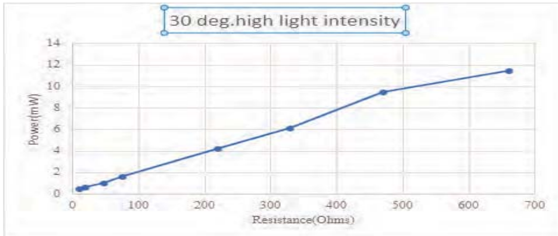

Figure 21 (d): R versus P incandescent bulb at 30° high light intensity

(e) Incandescent bulb at 45° less light intensity

TABLE V.
INCANDESCENT BULB AT 45 DEGREES LESS LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance(ohms)	Voltage(volts)	Current(mA)	Power(mA)
10	0.097	4.2	0.407
20	0.127	4.18	0.53
47	0.216	4.15	0.896
75	0.339	4.02	1.362
220	0.905	3.98	3.6
330	1.28	3.87	4.96
470	1.878	3.73	7.0
660	2.4	3.74	9.0

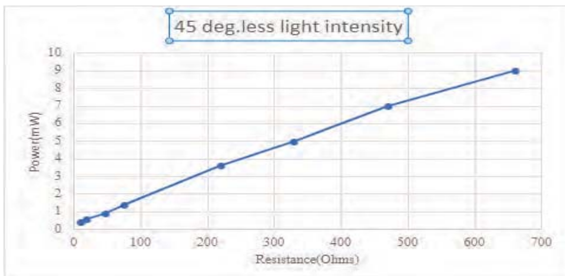

Figure 21(e). R versus P incandescent bulb at 45° less light intensity

(f) Incandescent bulb at 45° high light intensity

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TABLE VI.
INCANDESCENT BULB AT 45 DEGREES HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance(ohms)	Voltage(volts)	Current(mA)	Power(mW)
10	0.37	10.23	3.06
20	0.308	10.19	3.13
47	0.521	9.14	4.76
75	0.84	9.15	7.68
220	2.19	9.85	21.57
330	3.21	9.75	31.29
470	4.8	9.58	45.9
660	5.96	9.19	50.17

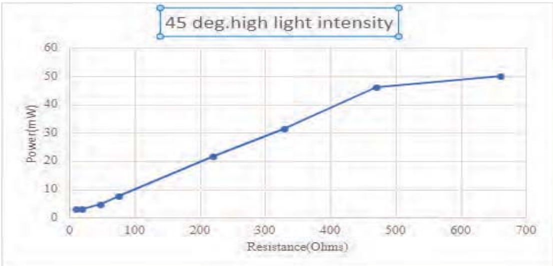

Figure 21 (f). R versus P incandescent bulb at 45° high light intensity

(g) Incandescent bulb at 60° degrees less light intensity

TABLE VII.
INCANDESCENT BULB AT 60 DEGREES LESS LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.13	6.25	0.81
20	0.191	6.31	1.205
47	0.328	6.21	2.04
75	0.516	6.09	3.14
220	1.329	5.91	7.8
330	1.89	5.74	10.84
470	2.94	5.64	16.58
660	3.58	5.52	19.76

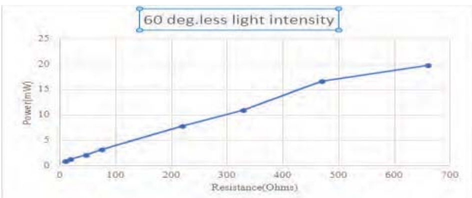

Figure 21 (g). R versus P incandescent bulb at 60° less light intensity

(h) Incandescent bulb at 60° degrees high light intensity

TABLE VIII.
INCANDESCENT BULB AT 60 DEGREES HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.414	17.84	17.385
20	0.54	17.6	9.504
47	0.356	17.45	23.66
75	1.5	17.28	25.937
220	3.74	16.73	62.57
330	5.37	16.33	87.69
470	7.84	15.52	121.67
660	8.27	12.78	105.69

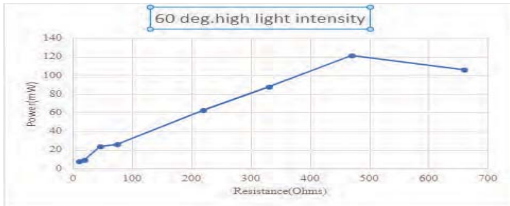

Figure 21 (h). R versus P incandescent bulb at 60° high light intensity

(i) Incandescent bulb at 75° degrees less light intensity

TABLE IX.
INCANDESCENT BULB AT 75 DEGREES LESS LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.18	8.76	1.57
20	0.268	8.75	2.34
47	0.512	8.65	4.42
75	0.742	8.58	6.36
220	1.874	8.32	15.59
330	2.634	8.05	21.2
470	4.08	7.64	31.17
660	5.06	7.54	38.15

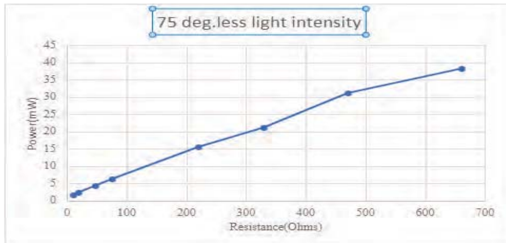

Figure 21 (i). R versus P incandescent bulb at 75° less light intensity

(j) Incandescent bulb at 75° degrees high light intensity

TABLE X.
INCANDESCENT BULB AT 75 DEGREES HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.334	27.1	9.05
20	0.59	26.9	15.87
47	1.19	26.2	31.23
75	1.95	25.2	49.14
220	5.19	24.3	126.11
330	7.53	23.6	177.7
470	8.44	16.6	140
660	8.65	13.37	115.65

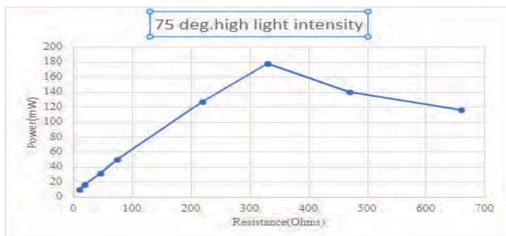

Figure 21 (j). R versus P incandescent bulb at 75° high light intensity

(k) Incandescent bulb at 90° less light intensity

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TABLE XI.
INCANDESCENT BULB AT 90 DEGREES LESS LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.198	16.8	3.32
20	0.362	17	6.15
47	1.03	16.8	17.43
75	1.27	16.9	21.59
220	3.64	17.2	62.69
330	5.4	17	91.93
470	7.26	14.8	107.44
660	7.84	12.3	96.43

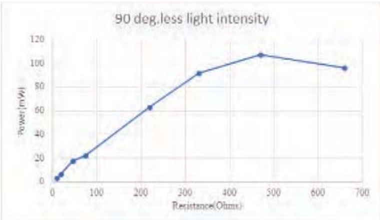

Figure 21 (k). R versus P incandescent bulb at 90° less light intensity

(l) Incandescent bulb at 90° high light intensity

TABLE XII.
INCANDESCENT BULB AT 90 DEGREES HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.66	30.2	19.9
20	0.674	29.9	19.3
47	1.414	29.4	41.5
75	2.18	28.8	62.9
220	6.05	28.3	171.21
330	7.83	24.5	191.83
470	8.41	17.1	143.6
660	8.61	13.5	116.23

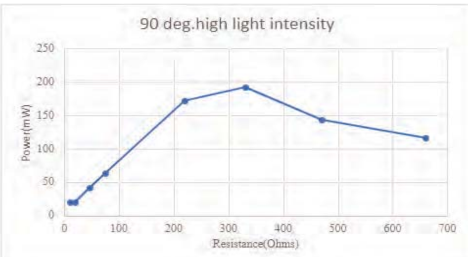

Figure 21 (l). R versus P incandescent bulb at 90° high light intensity

B. Solar panel at -23.5° and bulb at 90° high light intensity

TABLE XIII.
SOLAR PANEL AT -23.5^0 AND BULB AT 90^0 HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.243	19.6	4.76
20	0.426	19.5	8.307
47	0.974	19.3	18.79
75	1.62	19.1	30.94
220	4.02	18.8	75.57
330	5.93	18.2	107.9
470	7.59	15.13	114.83
660	7.99	12.32	98.43

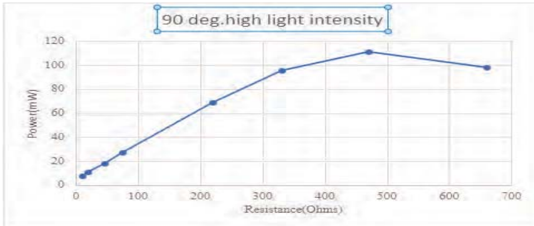

Figure 22. Solar panel at -23.5° R versus P incandescent bulb at 90° high light intensity

C. Solar panel at +23.5° and incandescent bulb at 90° high light intensity.

TABLE XIV.
SOLAR PANEL AT -23.5^0 AND BULB AT 90 HIGH LIGHT INTENSITY CLASSIFICATION PERFORMANCE

Resistance (Ohms)	Voltage (Volts)	Current(mA)	Power(mW)
10	0.417	18.55	7.735
20	0.572	18.4	10.524
47	0.978	18.11	17.711
75	1.54	17.74	27.319
220	3.928	17.45	68.54
330	5.62	17.05	95.82
470	7.5	14.84	111.3
660	7.99	12.27	98.03

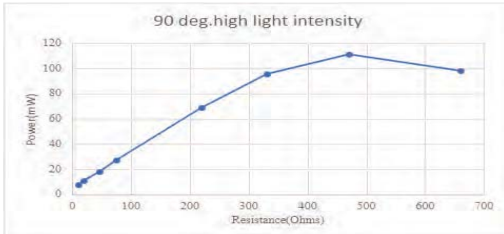

Figure 23. Solar panel at 23.5° R versus P incandescent bulb at 90° high light intensity.

Hence from all the results it is observed that the maximum power output comes from Solar panel at 0° and incandescent bulb light (high light intensity) at 90°.In this case the graph shows maximum power output at 330 ohms resistance.

VII. CONCLUSIONS

The solar panel parameters like voltage, current have been measured. At high light intensity, solar panels produce more power compared to less light intensity. The solar panel output characteristics are drawn between output power and load resistance. The future scope of this project is by changing the brightness of the light with degree of rotation per day of the year and time of the day. This paper can be extended as single axis, dual axis, no tracking. For future development, it is recommended that the framework be built with greater precision sensors and that it be able to retain information received from the estimates in order to ensure accurate monitoring and evaluation. Furthermore, the framework may be modified to use a DC supply from a battery, with a charging circuit added to allow the battery to be charged, making the framework more adaptable.

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