Fabrication and Testing of Microcontroller-based tracking of Dual-Axis Photovoltaic tracking system

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***Abstract*— In light of the growing need for energy and the gravity of environmental issues, renewable energy sources have emerged as a viable alternative to traditional fossil fuels. Renewable energy has enormous ecological and economic potential, and it is quickly becoming a new growth area for many countries. When it comes to powering homes and businesses, solar panels are invaluable, particularly in places that don't have access to the grid. Through the use of an Arduino Uno and a light-dependent resistor (LDR) sensor, we want to discover the optimal method for tracking the sun's movement in real-time. There are two parts to the project: developing the hardware and developing the software. The maximum light source for hardware development was recorded using four light dependent resistors (LDRs). Precise positioning of the solar panel is made possible by two servo motors and light-detection radar (LDR) technology. As part of our review, we compared the device's efficiency to that of a stationary solar panel. To get the most out of solar energy harvesting, this project details how to build a simple and inexpensive solar tracking system. The brains of the operation have been an Arduino Uno. The solar PV panel could be angled in any direction with the help of two servo motors, and its location could be tracked by four light-dependent resistors (LDRs). We have successfully integrated the servo motor and sensors. The PV panel and the servo motor have been linked by the mechanics. We made sure the system worked after assembly. This solar panel tracker ensures that the panel remains facing the sun continuously. The daily arc of the sun across the sky can be monitored using a two-axis solar tracker to keep solar panels running at their most efficient.**

I. INTRODUCTION

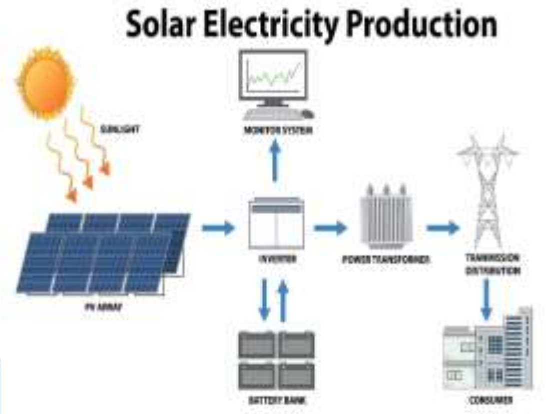
Our solar system's principal star, the 4.5-billion-year-old yellow dwarf star known as the Sun, provides the energy necessary for life on Earth. The Sun's core is the site of nuclear fusion, the process that produces an enormous quantity of energy. Hydrogen and helium constitute the majority of its composition, however it does include small quantities of other elements. The surface of this asteroid is 10,000 degrees Fahrenheit (5,500 degrees Celsius), while its inside can reach temperatures of over 27 million degrees Fahrenheit. If one hundred billion dynamite bursts could power the Sun for one second, it would be evidence of its vast power. There is no easy way to replace fossil fuels since they rely on finite resources that are either too costly or too risky to discover. At the current rate of usage, fossil fuels will surely be depleted at some point. Anxieties over these fuels' diminishing supplies are growing, and our present consumption habits are adding to the problem of rising atmospheric carbon dioxide, which is harmful to the environment. Solar power is an option that could help address some of the problems caused by fossil fuels. Solar power is one megawatt-and maybe infinite-watt energy source. The amount of solar power that Earth soaks up is around 1.8 X 10"MW. By a factor of thousands, this exceeds the present consumption of all commercial energy sources on Earth. Solar energy has the potential to meet all of humanity's energy demands indefinitely. Among the most exciting alternatives to traditional energy sources, it is highly regarded for this reason. One of the most promising renewable energy sources is solar power. If other national resources were to run out, even a tiny amount of this energy source might be exploited, making it one of the most significant.

Earth gets its energy from the Sun. It is this energy that causes the water cycle, atmospheric and oceanic currents, plants to be able to make oxygen through photosynthesis, and for the surface temperature to remain higher than in colder areas. The amount of solar power that can be collected by the Earth's surface is 10'6 watts, while the amount that can be collected by the region where the Sun meets the atmosphere is 1017 watts. To satisfy the electrical needs of every single person on Earth, 1,131 watts of power would be required. This allows us to harness 1,000 times more solar power than we use. It will be fifty times more than what the world requires, even if we just manage to harness 5% of this energy. On sunny days, the sun's energy output is approximately 1 kW/m2, and some have tried to harness this.Potentially used as power by the electrical generator's main movers. Due to the large amount of land needed and the unpredictability of the energy supply caused by factors such as clouds, winds, haze, etc., Producing electricity via this approach is not a good idea. Mechanical and electrical devices, converted hydrogen, and containers of eutectic or phase-changing salts are all viable options for energy storage, therefore claims that it is diluted and cannot be kept are out of date. In [2],

Among the stars that orbit Earth, the Sun stands out. It is a massive gas sphere with a surface temperature of about 5,780,000 Kelvin. The Sun, with a diameter of around 1.27 x 10^4 km, dwarfs Earth significantly. It is estimated that the diameter of the Sun is around 1.39 x 10^6 km. This enormous immensity is best illustrated by the Sun. Also, the Sun is enormously massive, with a mass about 332,000 times that of Earth. In spite of Earth's hourly and yearly revolutions around the Sun, it is still the most prominent and important celestial body in our solar system. On most occasions, Earth's distance from the Sun exceeds 150 x 10^6 km [3].

One way to harness the sun's rays and turn them into usable electricity is via photovoltaic solar cells. The electrification of rural communities in India mainly involves the use of solar cells to power irrigation pump sets and water purification systems [4]. This includes lightweight equipment like medical freezers, lighting, community televisions, and water purification systems.

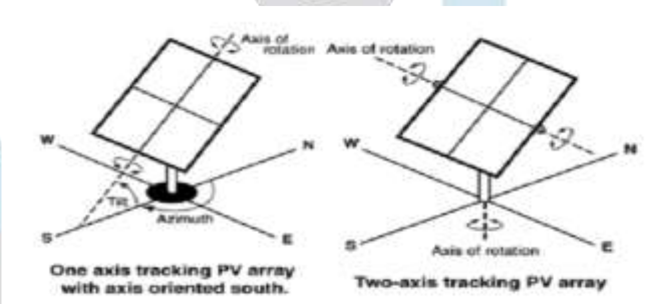
One easy way to turn solar energy into electricity is by using photovoltaic cells. This discovery has the potential to greatly benefit India's agricultural sector and rural development. The fundamental idea is that of light interacting with a semiconductor. The energy levels of the electrons in the semiconductor are raised when solar photons hit it. An internal electric field is required for these excited electrons to carry out practical tasks. Semiconductors like silicon, gallium arsenide, cadmium sulphide, and copper sulphide can produce electricity due to the field produced by a p-n junction inside the material.
[5].



Solar modules can be directed to track the sun's beams for optimal alignment and, by extension, solar energy generation. We have developed a number of tracking systems. New software is required for each of these tracking methods. To maximise the efficiency with which the solar array collects and converts sunlight into power, a tracker ensures that it remains perpendicular to the sun. Summer finds the sun at its highest point, while winter finds it at its lowest. The array is orientated ideally in the system if the local profile and the annual fluctuation or profile of insolation are consistent. The system with the tracker has a higher power output than the one without. Utilising the system tracker will result in a 25% increase in output.[6].

In most cases, tracking can be achieved using,

1. Transverse motion about the x-axis.
2. The process of spinning around an axis that is opposite and inclined to the polar axis, as well as the east-west axis

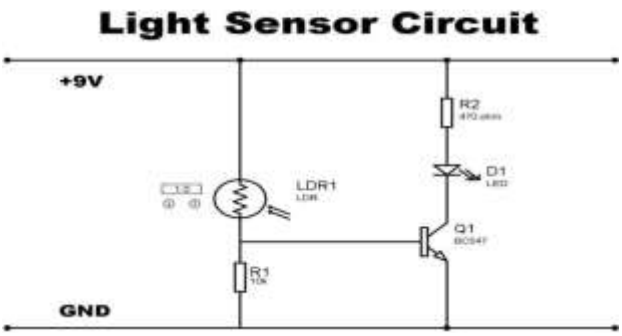


Every year, solar panels are maximised using one of two tracking technologies: one-axis tracking or two-axis tracking. Every day, one-axis trackers will move in the direction of the sun as it moves from west to east. The sun's arc is followed from dawn to dark by a typical design that permits a continual revolving speed of fifteen degrees per hour. Having an axis that is perpendicular to Earth's allows this to happen. The modules' angle of tilt with respect to the ground stays the same in this arrangement. The modules might not stay precisely above the earth all the time if they really do follow the sun's east-west path. As the sun circles around both of these axes, systems that follow one axis perpendicular to the local latitude and the other more traditional follow the sun's path, in contrast.

II. DUAL-AXIS TRACKING SYSTEM

Working principle:

In a light-dependent resistor (LDR), the resistance increases as the light intensity increases. In instance, the resistance goes down as the light level rises and back up again when the light level falls. The ability to sense light is a feature of light-dependent resistors. Because the LDR has a low resistance, the output voltage decreases as the light intensity rises. On the other hand, as the light level drops, a high-resistance LDR will produce a higher voltage output. The most reliable method for sensing and converting changes in LDR resistance into an output voltage is a potential divider circuit.

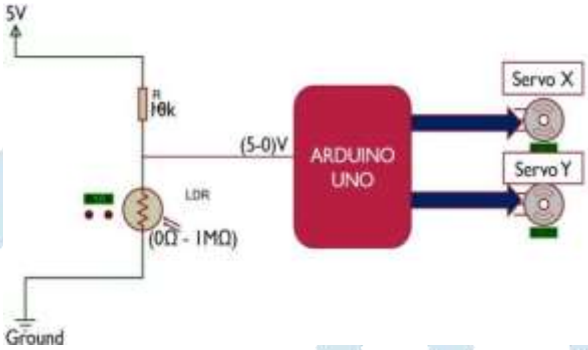


LDRs work by taking an analogue input voltage ranging from 0 to 5 volts and converting it to a digital value ranging from 0 to 1023. At this point, the microcontroller can be controlled by the technique discussed later in the hardware model; the Arduino IDE will begin providing this information back at this point.

The following is the schematic of the solar tracker's dual-axis circuit. The 5V supply for the Arduino Board is supplied by a USB 5V dc power source.

Motor X: Spins the solar panel in the X-direction

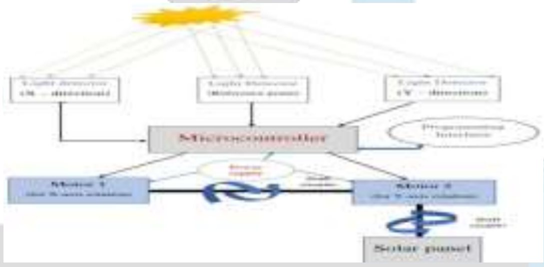
Turns the solar panel in the Y-direction (servo Y).



III. HARDWARE AND SOFTWARE USED FOR TRACKING SYSTEM

Many different methods for classifying processes are presented in RP literature. German manufacturing laws provide the basis for this graphic, which illustrates one technique of classifying RP procedures according on the amount of raw materials used.

ARDUINO UNO:

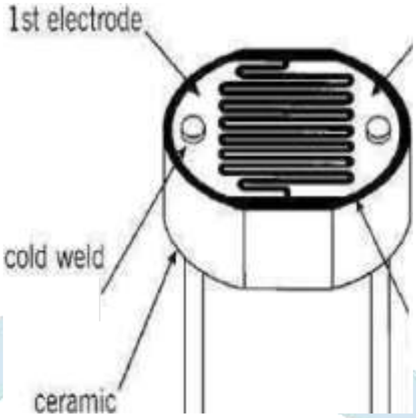


The Arduino Uno is just one of many boards that employ the ATmega328 microprocessor. The Arduino platform is great for making prototypes since it is both easy to use and open source. Several features are featured on the Arduino Uno, including a power jack, an ICSP header, a reset button, a USB connection, a crystal oscillator running at 16 MHz, and fourteen digital input/output pins, six of which can be utilised as PWM outputs. Everything you need to get started, including a battery, an AC-to-DC adapter, or a USB cable, is already there to support the microcontroller. Unlike its predecessors, the Arduino Uno doesn't rely on the FTDI USB-to-serial driver chip. A USB-to-serial converter is built into the Atmega8U2 CPU instead. Aiming towards the imminent launch of Arduino, the name "Uno" was chosen from the Italian word for "one." The Arduino Uno and its version 1.0 will be the de facto standards for Arduino moving forward. The Uno, the most recent in a line of USB Arduino boards, serves as the platform's yardstick. [23].

HARDWARE PARTS REQUIRED FOR TRACKER:

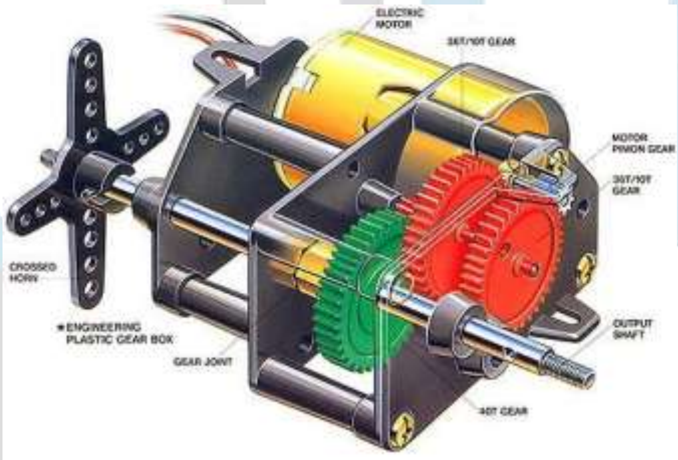
LDR:

One kind of electrical component that alters its electrical resistance when exposed to electromagnetic radiation is a photoresistor, photocell, or photoconductive cell. It is also known as light-dependent resistors (LDRs). To put it simply, it is a resistor that is sensitive to changes in light. The semiconductors used to build these devices have a very high resistance when no light is present. The energy that light provides is what allows a light-dependent resistor (LDR) to work. When a material may increase its electrical conductivity by absorbing light, this phenomenon is called photoconductivity. The most popular kind of light-dependent resistor (LDR) has a decreasing resistance as the light intensity increases.



SERVO MOTOR:

Included in an all-in-one DC servo motor are motor driving electronics, a small DC motor, a gearbox, and an electronic feedback control loop. Like a standard DC motor, it appears and operates in the same way. A permanent magnet is housed within the stator, which is a cylindrical component. Current flows into the commutator from the rotor's armature coil. A speed detector is built inside the rotor shaft. This design makes it easy to create a controller with few reasoning requirements because the torque of the motor is exactly proportional to the current passing through its armature. [24]



DESCRIPTION OF THE SOFTWARE PROGRAM:
STEPS-

1. **Servo Initialization:** The mechanism is controlled by two servo motor components.
2. 2. Factors Connected to Jobs Two variables, Pos(x) and pos(y), store the locations of the servos that are to be targeted.
3. **LDR Configuration:** 2. Job-Related Elements To pinpoint which servos to aim towards, we need two variables: Pos(x) and pos(y).
4. **Servo Attachment:** Specific digital pins are used to connect the servo motors.
5. **Analog Pin Setup:** Using the pinMode() function, the LDRs' analogue input pins can be set.
6. **Initial Position:** Following a pause of one second, the servos are returned to their initial or intermediate positions.
7. **Analog Readings:** Three variables are used to convert the analogue LDR values into integers ranging from 0 to 1023.
8. **Position Adjustment Logic:** The servos will maintain their present position if the tolerance is less than the difference between two LDR readings. If this is not the case, then the pos(x) and pos(y) values are adjusted to send the servos in a direction with less light.
9. **Servo Movement:** The calculated position values are to be received by the servos. The loop ends when the input values are out of range by more than the tolerance.
10. **Position Limiting:** The only possible range for the servo positions is 30° to 150°. If the position is more than 150°, its value is set to 150°. If it falls below that, it is changed to 30 degrees.

IV. DISCUSSION AND OBSERVATION

Solar panels must be positioned to capture sunlight before they can be connected to a load in order to harness the power they generate. The efficiency with which the solar tracker maintains its direction and the amount of light reaching the panel are directly proportional to the voltage output of the panel. Concentrated solar photovoltaic systems rely on sunlight tracking. Precision tracking is essential for these devices to harvest energy from the sun, as they use optics to concentrate the light into a smaller surface. For the solar panel to produce the most energy possible, the tracking mechanism and light-dependent resistors work together to maximise the quantity of light that reaches the panel. A solar panel's maximum load capacity is determined by its electrical properties.

DUAL-AXIS MOVEMENT OF SOLAR TRACKER

- Using its light-detecting capabilities, the dual-axis solar tracker can find its way to areas with the strongest sunlight. It can follow light from any direction thanks to its form.

- In order to mimic the Sun's whole motion, the tracker's coverage in both directions is taken as 120˚.
- • No matter the orientation (east-west or north-south), every servo motor starts at an exact angle, 90˚.
- When the threshold value goes beyond the tolerance limit, the tracker's location will only change.

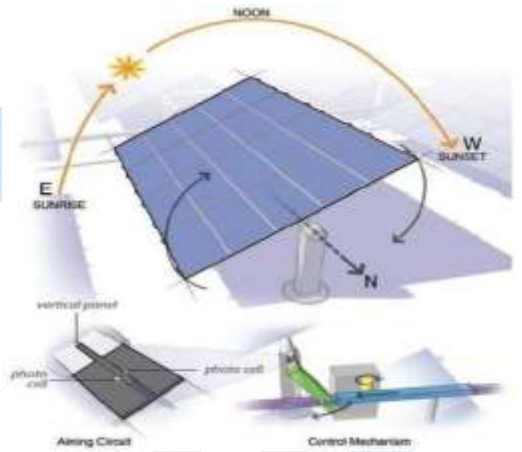


Fig. solar panel movement

V. RESULT

1. This Dual Axis Solar Tracker allows you to tilt the panel so that it absorbs the sun's rays when they're at their strongest.
2. The project's objective has been met. By tracking the amount of light reaching the solar panel, we were able to accomplish this with the use of light sensors. Using a servo motor, the panel is adjusted until it is nearly perpendicular to the sun's rays. After that, any noticeable change is identified by comparing the LDR readings.
3. This was accomplished by a three-step process. At each level, there is a distinct purpose. There was a
4. A light-sensitive stage that converted light into voltage.
5. The control stage oversaw the actuators and decision-making process.
6. A driving stage with servo motors. It controlled the actual movement of the panel.
7. A voltage divider circuit is integrated into the input stage to ensure an adequate range of illumination in both bright and dim lighting conditions.
8. The potentiometer was adjusted to compensate these variances. The light-dependent resistors (LDRs) were the ideal option for our research because of this.
9. You can easily find them and they are inexpensive. For instance, setting up temperature sensors would be a costly proposition.
10. A microprocessor in the control stage determines the next step after receiving voltages from the LDRs.
11. The microprocessor sends a signal to the servo motor, which moves in reaction to the error, as programmed.
12. Step twelve included the drive circuitry, which mostly included the servo motor. The servo motor has plenty of torque, which might be used to drive the panel.
13. servo motors are the best choice because they are quiet and don't cost too much.

EXPERIMENTAL RESULTS:

A dual-axis photovoltaic solar tracking system based on microcontrollers was designed and tested by us. Making a table with all the findings of comparing various tracking methods is the next step. The structure is connected to the solar panel. Its base is at a right angle to the sun. The output of the solar panels is utilised by this integrated dual-axis photovoltaic solar tracking system to determine the outcomes. It contains an Arduino UNO board as its microcontroller.

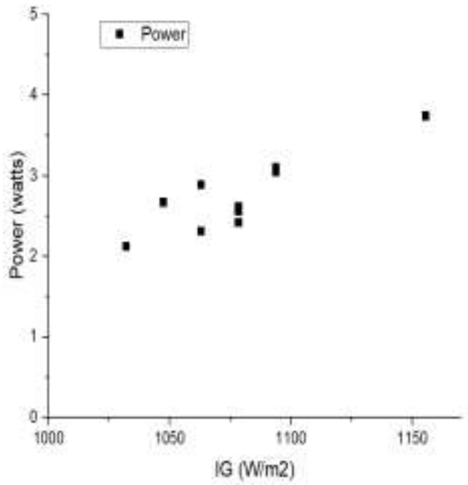
1. 1. Experimental data on radiation, power, and solar panel efficiency are included in the tables below for both the two- and one-axis tracking systems.

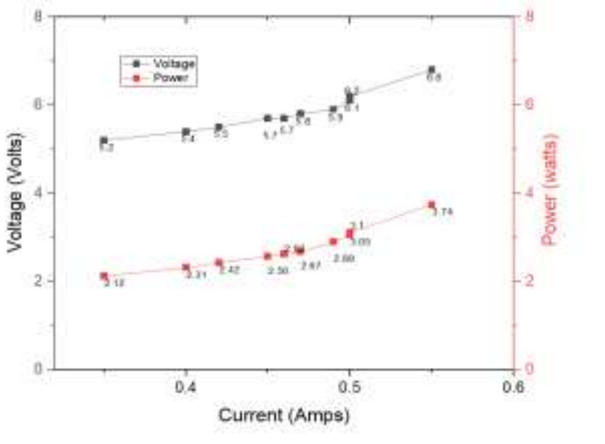
Power generated	**= I x V(watts)**
Radiation from pyranometer	**= mv**
Radiation in W/m^2	**= 154.5 x (mv) - 3.2**
Area of panel	**= 0.0036m^2**
Efficiency of panel	**= (power x 100)/(Ig x Area of the panel).**

Dual-Axis tracking system

DATE	CURRENT (I)	VOLTAGE (V)	POWER (W)	Ig (mv)	Ig (W/m^2)	EFFICIENCY %
11-Oct	0.4	5.8	2.42	7	1078.3	6.562203
12-Oct	0.35	5.2	2.12	6.7	1031.95	6.00691
14-Oct	0.46	5.7	2.62	7	1078.3	7.104534
15-Oct	0.5	6.2	3.1	7.1	1093.75	8.287385
20-Oct	0.45	5.7	2.56	7	1078.3	6.941834
21-Oct	0.42	5.5	2.31	6.9	1062.85	6.354976
26-Oct	0.55	6.8	3.74	7.5	1155.55	9.463608
27-Oct	0.47	5.4	2.67	6.8	1047.4	7.453712
28-Oct	0.49	5.9	2.89	6.9	1062.85	7.950597
29-Oct	0.5	6.1	3.05	7.1	1093.75	8.153718

<u>CHARTS USING A TWO-AXIS SYSTEM:</u>

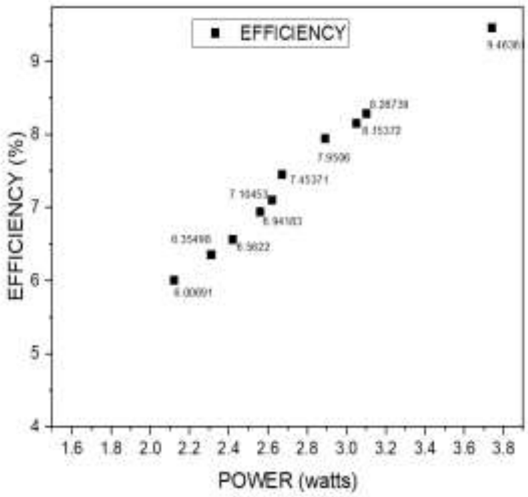


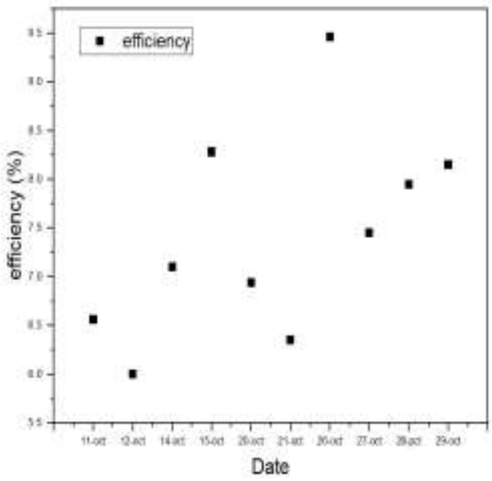


The power and voltage seen in the graph above increase in direct proportion to the current. Visual inspection of the graph reveals a relationship between the square of the input current and the power output.

An increase in solar incidence will lead to an increase in output, as seen in the above graph, if IG (radiation) is the natural source.

Up there you may see a graph that shows power vs efficiency. It demonstrates that the efficiency of solar panels increases as the power output does.





Depending on the weather and climate, the radiation levels fluctuate during the day, as seen in the graph above.

2. Power, radiation, and efficiency of the solar panels are all shown in the following table. It also includes the single axis tracking mechanism.

3. A tracking system with a single axis

DATE	CURRENT (I)	VOLTAGE (V)	POWER (W)	Ig (mv)	Ig (W/m^2)	EFFICIENCY %
11-Nov	0.32	3.9	1.248	6.7	1031.95	3.536143
12-Nov	0.37	4.2	1.554	6.9	1062.85	4.275165
14-Nov	0.39	4.3	1.677	7	1078.3	4.547444
15-Nov	0.39	4.3	1.677	7	1078.3	4.547444
20-Nov	0.4	4.4	1.76	7.1	1093.75	4.705096
21-Nov	0.37	4.2	1.554	6.9	1062.85	4.275165
26-Nov	0.41	4.3	1.763	7.1	1093.75	4.713116
27-Nov	0.39	4.2	1.638	6.8	1047.4	4.572726
28-Nov	0.39	4.27	1.665	6.8	1047.4	4.648101
29-Nov	0.39	4.29	1.673	6.9	1062.85	4.602543

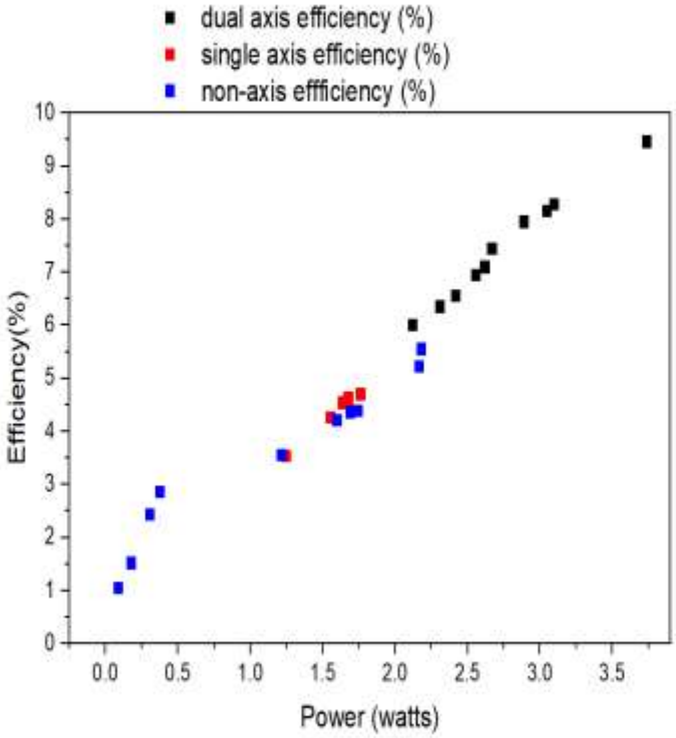
4. The following are the values of the non-tracking system, radiation, power, and efficiency of the solar panels:

Non-tracking system

DATE	CURRENT (I)	VOLTAGE (V)	POWER (W)	Ig (mv)	Ig (W/m^2)	EFFICIENCY %
11-Dec	0.08	1.1	0.088	1.6	244	1.054549
12-Dec	0.11	1.6	0.176	2.2	336.7	1.528423
14-Dec	0.14	2.2	0.308	2.4	367.6	2.449904
15-Dec	0.15	2.5	0.375	2.5	383.05	2.862528
20-Dec	0.32	3.8	1.216	6.5	1001.05	3.551826
21-Dec	0.39	4.1	1.599	7.2	1109.2	4.215145
26-Dec	0.4	4.23	1.692	7.3	1124.65	4.399029
27-Dec	0.49	4.42	2.1658	7.4	1140.1	5.554555
28-Dec	0.41	4.26	1.7466	7.6	1171	4.361245
29-Dec	0.49	4.45	2.1805	7.9	1217.35	5.237385

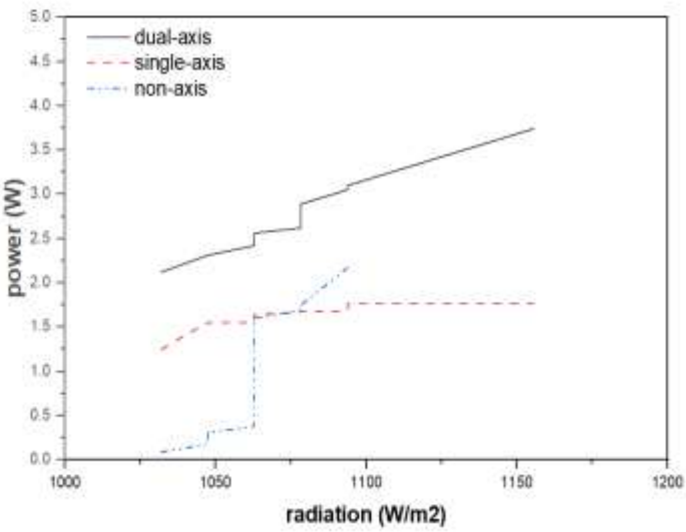
GRAPHICAL COMPARISION:

1. For varying values of the dual axis, efficiency is plotted on the y-axis, and power is plotted on the x-axis, and non-tracking systems. Various tracking systems' improved efficiency can be easily observed in this graph.



As seen in the previous graph, the dual-axis tracking system outperforms both non-tracking and single-axis systems in terms of efficiency.

2. An x-axis representing radiation and a y-axis representing power is generated for a range of values on the dual, single, and non-tracking axes. The graph displays the evolution of power values for various tracking systems.



An x-axis representing radiation and a y-axis representing power is generated for a range of values on the dual, single, and non-tracking axes. The graph shows that the power values of various tracking systems have been improved throughout time.

CONCLUSION

Energy consumption per person has increased dramatically in the twenty-first century due to several variables such as population expansion and technological improvements. The same time, conventional energy sources like fossil fuels are running out quite quickly. To achieve sustainable growth, we need to find ways to satisfy our increasing energy demands, and one option is to look into renewable energy and other alternative sources. Our goal here is to build a demonstration model of a two-axis solar tracker. Finding and maintaining the optimal point of light intensity, where the solar panel can produce the most electricity, is the major purpose of this tracker. After much testing and optimisation, the project was ultimately finished, marking a significant step towards solving society's energy problems. Having said that, the effort does have some limitations, as do all experimental endeavours. The inbuilt light sensors of the solar panels have a limited sensing range, which is the first issue. The tracker's sensitivity to variations in light intensity becomes significantly weaker beyond this distance. Second, in cloudy conditions with several light sources, such scattered sunshine, the algorithm calculates the optimal location for the panels to be deployed by summing up all the vectors of the different light sources. Perhaps this isn't always the best spot for collecting energy. Due of the limited resources available, the circuitry was intentionally kept basic, intuitive, and user-friendly.

REFERENCES

[1] t. https://www.mpg.de/18652392/new-calculations-of-solar-spectrum-resolve-decade-long-controversy-about-the-sun-s-chemical-composition#:~:text=Cecilia%20Payne%2DGaposchkin's%20realization%20that.

[2] manoa.hawaii.edu/exploringourfluidearth/physical/atmospheric-effects/wind-formation, “https://manoa.hawaii.edu/exploringourfluidearth/physical/atmospheric-effects/wind-formation”.

[3] sun, “https://en.wikipedia.org/wiki/Sun#:~:text=From%20Earth%2C%20it%20is%201,109%20times%20that%20of%20Earth.”.

[4] i. //Photoelectric_effect#:~:text=In%20the%20photoemission%20process%2C%20when, “photoelectric effect,” https://en.wikipedia.org/wiki/Photoelectric_effect#:~:text=In%20the%20photoemission%20process%2C%20when,its%20binding%20energy%2C%20it%20is.

[5] “solar photovoltaic cell,” https://www.energy.gov/eere/solar/solar-photovoltaic-cell-basics#:~:text=This%20current%20is%20extracted%20through,and%20the%20rest%20of%20the.

[6] D. Mitra, D. Das, D. Brahma, D. Maiti and T. Mondal, “Sun Tracking Solar Panel Without Microcontroller,” ieee xplore, kolkata, 2019.

[7] J. Y. Muhammad, “A Review on Solar Tracking System: A Technique of Solar Power Output Enhancement,” reacherch gate, 2019.

[8] barsoum.N, “design and implementation of a two axes sun tracking system,” *global journal on technology,* pp. 1-6, 2010.

[9] T. tudorache, “performance of a single axis solar tracking pv panel,” *U.P.B. Scientific Bulletin series C: electrical engineering and computer science,* vol. 74(2), no. 115-124, 2012.

[10] J. Rizk, “Design and implementation of a simple sun tracking system,” *world academy of science,engineering and technology,* vol. 41, pp. 444-448, 2008.

[11] M. M. .. Arturo, “ Sun tracking system using a commercial webcam as a sensor,” *WSEAS Transactions on Environment and Development,* vol. II(2), pp. 126-135, 2010.

[12] S. Abdallah, “Enhancing the productivity of solar stills using a computerized sun tracking system,” *Desalination ELSEVIER,* Vols. 220(1-3), pp. 669-676, 2008.

[13] M. R. I. Sarker, “Design, construction and experimental study of a two axis automatic solar tracking system.,” *nternational Journal of Mechanical and Mechatronics Engineering,* vol. 10, no. 1, pp. 1-6.

[14] Rubio, F. R., Valero, F., Casanova, F., & Romero, R., “ A hybrid open-loop/closed-loop control strategy for two-axes solar trackers,” *Energy Conversion and Management,* vol. 48, no. 7, pp. 2174-2184, 2007.

[15] Roth, P., Löffler, A., & Quaschning, V, “ Design and operation of an automatic sun tracking system.,” *Renewable Energy,* vol. 29, no. 3, pp. 393-402, 2004.

[16] Huang, B. J., Chen, C. S., & Chou, P. C., “Optimal design and analysis of one-axis three-position sun tracking PV module with low concentration ratio reflector,” *Energy Conversion and Management,,* vol. 48, no. 4, pp. 1273-1280, 2007.

[17] Mousazadeh, H., Alimardani, A., & Shahriari, A., “ Maximization of collected energy from an on-board PV array on a solar assist plug-in hybrid electric tractor,” *Journal of Solar Energy Engineering,* vol. 133, no. 4, 2011.

[18] U. K. e. a. Okpeki, “Design and construction of a bi-directional solar tracking system,” *International Journal of Engineering & Science,* , vol. 2, no. 7, pp. 32-38, 2013.

[19] Balabel, A., El-Metwally, M., & Tolba, M. A, “Optimal control of solar photovoltaic module based on sun tracking system,” *International Journal of Control, Automation and Systems,* vol. 11, no. 6, pp. 1273-1280, 2013.

[20] Madhu, K. S., Kumar, K. D., & Babu, K. A, “Performance analysis of single and two axis solar tracker,” *International Journal of Scientific & Engineering Research*, vol. 3, no. 7, pp. 1-4, 2012.

[21] Badran, O., Abu-Rumman, A., & Jaradat, M, “ A new tracking approach of water distillation taking advantage of high possible concentration of parabolic trough collector,” *International Journal of Mechanical and Mechatronics Engineering*, vol. 1, no. 1, pp. 1-6, 2013.

[22] s. sharma, “Development and performance evaluation of solar thermal collector for grain drying.,” *International Journal of Advanced Engineering Research & Studies*, vol. 1, no. 2, pp. 162-166, 2012.

[23] “uno r3,” https://docs.arduino.cc/hardware/uno-rev3/.

[24] “motors,” https://ecampusontario.pressbooks.pub/btec315biomedicalinstrumenttroubleshooting/chapter/troubleshooting-electronic-motors/#:~:text=Stepper%20motors%20control%20the%20position,with%20a%20feedback%20control%20mechanism..

[25] “resistor,” https://en.wikipedia.org/wiki/Resistor#:~:text=In%20electronic%20circuits%2C%20resistors%20are,active%20elements%2C%20and%20terminate%20transmission.

[26] https://en.wikipedia.org/wiki/Axial_tilt.

[27] S. Sharma, “Development and performance evaluation of solar thermal collector for grain drying,” *International Journal of Advanced Engineering Research & Studies*, vol. 1, no. 2, pp. 162-166, 2012.