DESIGN AND DEVELOPMENT OF AUTOMATIC AND MANUAL OPERATED SUN TRACKER FOR DUAL AXIS SOLAR PANELS

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Abstract:

There are stationary based solar panels are existing in wide range. It does not possess the constituently maximum power. It cant rotate in any direction hence total utilization of energy is not possible in stationary based solar panel. To overcome this problem, the design and development of a dual axis solar tracker using 2 motors and sensors and an Arduino board became best solution. Its' efficiency is increased by 40-50% with less cost. With the aid of an Arduino Nano board, the proposed solar tracker that automatically tracks the sun to capture the greatest solar power was successfully completed.

1. INTRODUCTION

A variety of cutting-edge technologies, including solar, thermal photovoltaic etc are used to transmit solar energy, which is the heat and radiant light from the sun. It is only due to the high construction and maintenance costs of the power grid. The solar photovoltaic module directly transforms solar energy into electrical energy. There are numerous uses for photovoltaic energy today, including battery charging, water pumping, home power generation, water heaters, street lighting, satellite power systems, etc. They have the great advantage of being maintenance-free and pollution-free despite the high installation costs. The main challenge is to maximize the amount of sunlight that is absorbed by the solar panels in order to produce the most electricity. There are two ways to increase the output power of solar energy-based systems. Either a solar tracker or an efficient material can be used to create PV cells, which track the sun. Solar Tracker will function like a sunflower in this project. The foundation of this project is the use of optical or LDR sensors to track the sun. Geared DC motors that are driven by a programmed circuit move the panel in both the North-South and East-West directions under control of the panel movement. The LDRs are used to process the input.

An autonomous sun-tracking device was presented by Mayank Kumar Lokhande. He created a microcontroller-based solar panel tracking system and found that the single-axis tracker enhances efficiency over the fixed module by 30%[1]. The single-axis solar tracker was created by Imam Abadi, Adi Soeprijanto, and Ali Mustafa using fuzzy logic. To increase the power of the PV panel, they use an ATMEGA 8353 microcontroller with a fuzzy logic controller. They discovered that the PV panel had maximized and exceeded the stationary system by up to 47%[2].

A clever dual-axis solar tracker was provided by Dhanalakshmi. V and Lakshmi Prasanna H.N. They developed their suggested concept using an Arduino Uno. Following the trial, they discovered that the maximum voltage was tracked between 25% and 30%, and the generating power increased by 30% in comparison to the static system [3].

M.M. Abu Khader observed an experiment on the benefits of using two-axis sun tracking systems in the Jordanian environment. When compared to a static system for a specific day, they discovered that the power outcome had improved by 30-45% [4].

2. PROBLEM DEFINITION:

- Nowadays the existing solar panels are stationary based as they do not possess consistently maximum power output. Its efficiency is 40-50%.
- The Stationary Solar panels do not rotate in any direction & hence, efficiency is less.
- Stationary panel plants are highly expensive.
- For installation, the requirement of panels is more & it requires a huge space and more Sunlight.

3. SOLUTIONS:

By discussing no. of alternative solutions to above problem, we had done the project on, Design & Development of Automatic & Manual Operated Sun Tracker for Dual Axis Solar Panel. In this, we developed and designed a dual axis solar tracker using 2 motors and sensors and an Arduino board. Its' efficiency is increased by 40-50% with less cost.

4. METHODOLOGY:

4.1 : Design of Dual Axis Tracker Circuit

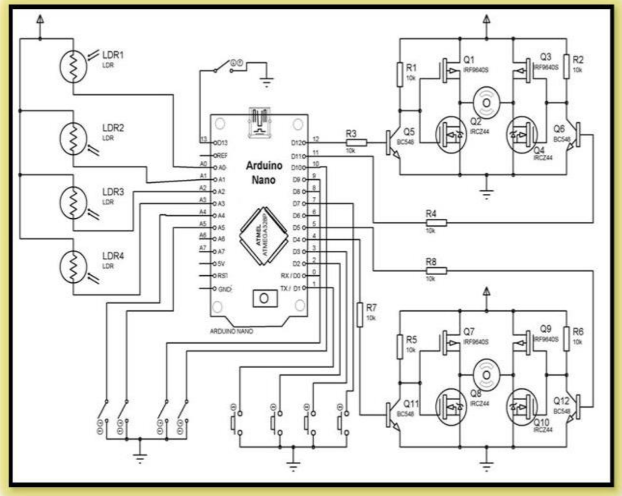
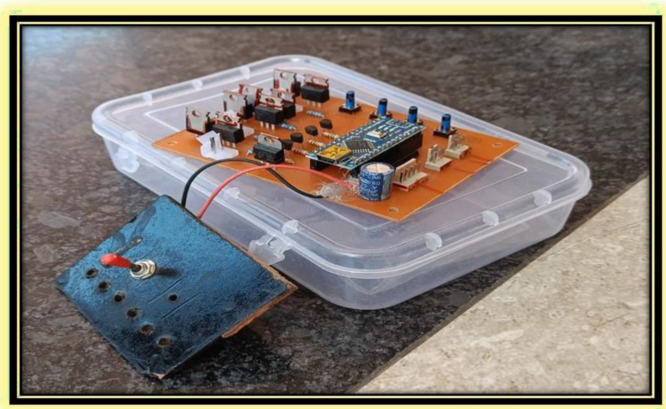


Fig. 1:- Design of Dual Axis Tracker Circuit

4.2 Working:-

- The circuit consists of Arduino nano as main controller board. The four LDR's used to detect the light intensity. MOSFETs are used to drive the motors. Two Gear motors are used to rotate the solar panel is X directions and Y direction. Four limit switches are used to detect maximum rotation of both axes. Four press switches are used to rotate the solar panel in both axes manually.



Photograph No.1:- Dual Axis Tracker Circuit

- The intensity of the light depends on Resistance of LDR, and it varies according to it. The higher is the intensity of light, lower will be the LDR resistance and due to this the output voltage lowers and when the light intensity is low, the LDR resistance will be higher and thus higher output voltage is obtained.

- If arduino is set in auto mode then arduino measures the output of four LDRs and calculate average of upper side and lower side outputs.
- If upper side output is greater than lower side output it means that light falling on upper side is greater than lower side. So the arduino gives signal to motor driver and rotates the solar panel to upper side.
- If upper side output is less than lower side output it means that light falling on upper side is less than lower side. So the arduino gives signal to motor driver and rotates the solar panel to lower side.
- The arduino measures the output of four LDRs and calculate average of right side and left side outputs.
- If right side output is greater than left side output it means that light falling on right side is greater than left side. So the arduino gives signal to motor driver and rotates the solar panel to right side.
- If right side output is less than left side output it means that light falling on right side is less than left side. So the arduino gives signal to motor driver and rotates the solar panel to left side.
- If Arduino is set in manual mode then solar panel can be rotated using press buttons.
- If button 1 is pressed then arduino gives signal to motor driver and rotates the solar panel to upper side.
- If button 2 is pressed then arduino gives signal to motor driver and rotates the solar panel to lower side.
- If button 3 is pressed then arduino gives signal to motor driver and rotates the solar panel to right side.
- If button 4 is pressed then arduino gives signal to motor driver and rotates the solar panel to left side.

The processes consist of following elements;

- Sensing.
- Microcontroller.
- Motor Driver.
- Motor Working with Sensor.
- Movement and Rotation of PV Panel.

4.3.Programing:

The programming language used by Arduino, an open-source platform, is based on C++ coding, and the logic employed in programming is done through control algorithms.

4.4 Dual Axis Solar Tracker Block Diagram

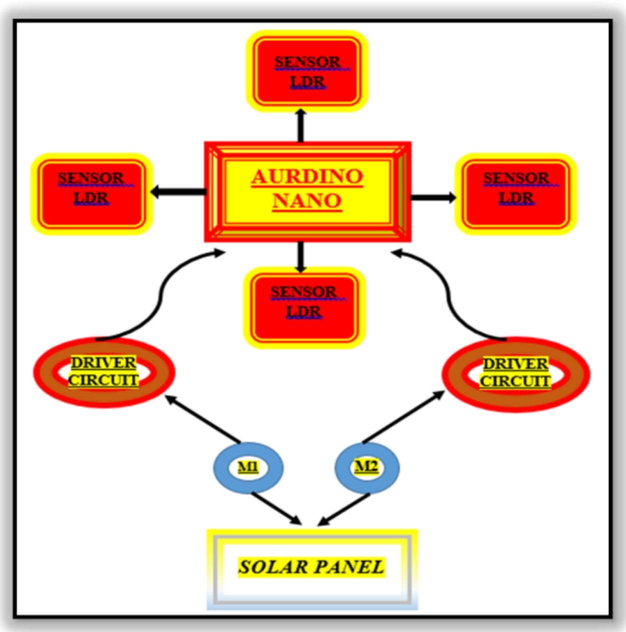


Fig.2: Dual Axis Solar Tracker Block Diagram

4.5 Control Algorithm:-

A) Control Algorithm Steps:-

1. Initialization of I/O pins.
2. Check the switch position
3. Arduino is set in auto mode then Arduino
4. Measure the output of four LDRs and calculate the average of the upper side and lower side outputs.

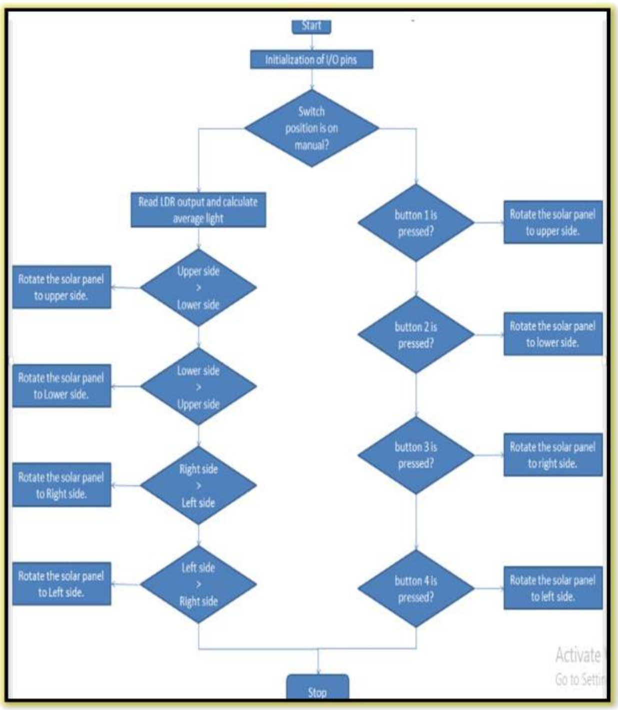


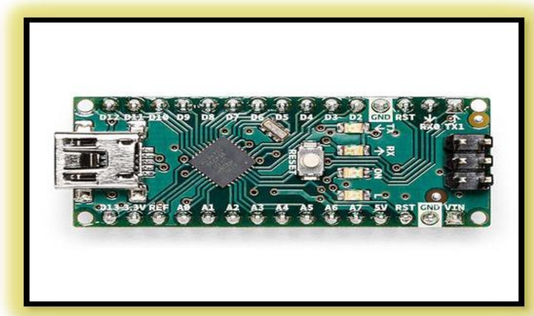
Fig.3: Control Algorithm

5. If the upper side output is greater than the lower side output, rotate the solar panel to the upper side.
6. If the lower side output is greater than the upper side output, rotate the solar panel to the lower side.
7. If the right side output is greater than the left side output, rotate the solar panel to the right side.
8. If the left side output is greater than the right side output, rotate the solar panel to the left side.
9. Arduino is set in manual mode.
10. If button 1 is pressed then rotate the solar panel to the upper side.
11. If button 2 is pressed then rotate the solar panel to the lower side.
12. If button 3 is pressed rotate the solar panel to the right side.
13. If button 4 is pressed then rotate the solar panel to the left side.

B) Dual Axis Tracker Component Details:-

i) Electronic Components:-

1. Arduino Nano:-



Photograph No. 2: Arduino Nano

Overview: Based on the ATmega328, the Arduino Nano is a compact, comprehensive, and breadboard-friendly board. It comes in a different packaging but has roughly the same capabilities as the Arduino Duemi lanove. It only lacks a DC power jack and uses a Mini-B USB cable rather than a conventional one to operate.

- Power: The Mini-B USB port, a 6-20V unregulated external power source (pin 30), or a 5V regulated external power supply (pin 27) can all be used to deliver power to the Arduino Nano. The greatest voltage source is automatically chosen as the power supply.
- Memory: The ATmega328 contains 32 KB of memory, 2 KB of which are reserved

for the bootloader. Two KB of SRAM and one KB of EEPROM make up the ATmega328.

- Input and Output: Using the pinMode(), digitalWrite(), and digitalRead() functions, each of the Nano's 14 digital pins can be utilised as an input or an output. They use 5 volts to work. Each pin includes a 20–50 kOhm internal pull-up resistor that is unconnected by default and has a maximum current capacity of 40 mA. Additionally, several pins perform specific tasks:
- Serial: 0 for RX and 1 for TX: Used to transmit and receive TTL serial data (RX and TX). The FTDI USB-to-TTL Serial chip's matching pins are connected to these pins.
- External Interrupts: 2 and 3. These pins can be set up to initiate an interrupt in response to low values, rising or falling edges, or value changes. Details can be found in the attach Interrupt() function.
- PWM: 3, 5, 6, 9, 10, and 11. The analog Write() method outputs an 8-bit PWM signal.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins enable SPI communication, which the underlying hardware supports but is not yet supported by the Arduino language.
- LED: 13. Digital pin 13 is wired to a built-in LED. The LED is on when the pin has a HIGH value; it is off when the pin has a LOW value.
- The Nano features 8 analogue inputs, each with a resolution of 10 bits (1024 distinct values). but the analog Reference function allows you to adjust the upper limit of their range. Digital pins cannot be connected to analogue pins 6 and 7. Additionally, certain pins are designed to do specific tasks:
- I2C: SDA (A4) and SCL (A5). Utilise the Wire library to support I2C (TWI) communication; documentation is available on the Wiring website.
- Other pins on the board include the following:
- AREF: The analogue inputs' reference voltage. When combined with analog Reference().
- Reset: For the microcontroller to be reset, bring this line LOW. Usually applied to shields that obstruct the board's reset button.
- Communication: The Arduino Nano provides several features for interacting with a computer, other Arduino boards, or other microcontrollers. UART TTL (5V) serial communication is offered by the ATmega328 and is accessible on digital pins 0 (RX) and 1 (TX). This serial connection is routed through USB by an FTDI FT232RL on the board, and the FTDI drivers (included with the Arduino software) give computer applications access to a virtual com port [5].
- Programming: The Arduino software can be used to programme the Arduino Nano. From the Tools - Board menu, choose "Arduino Duemilanove or Nano w/ ATmega328" (depending on the Microcontroller on your board). The boot loader on the preburned ATmega328 in the Arduino Nano enables you to upload new code to it without using an external hardware programmer. It uses the original STK500 protocol for communication. Additionally, you can use Arduino ISP or a similar programme to programme the

microcontroller directly through the ICSP (In-Circuit Serial Programming) interface, bypassing the boot loader.

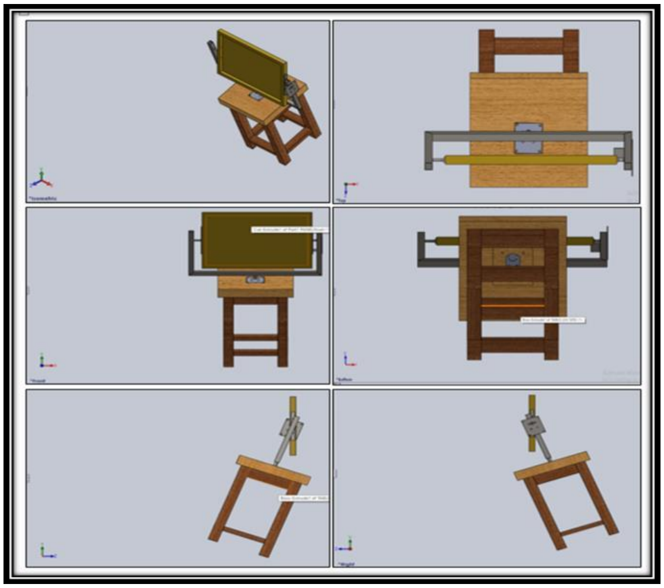


Fig. 4 : Isometric Views of Assembly of Overall Model

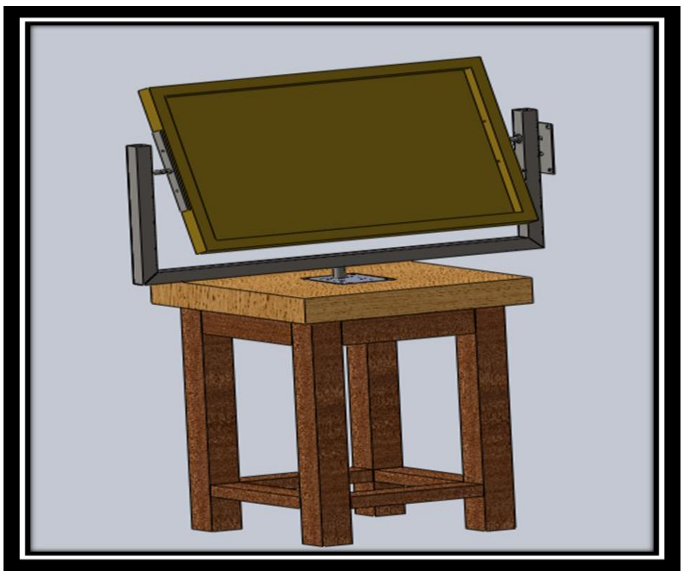
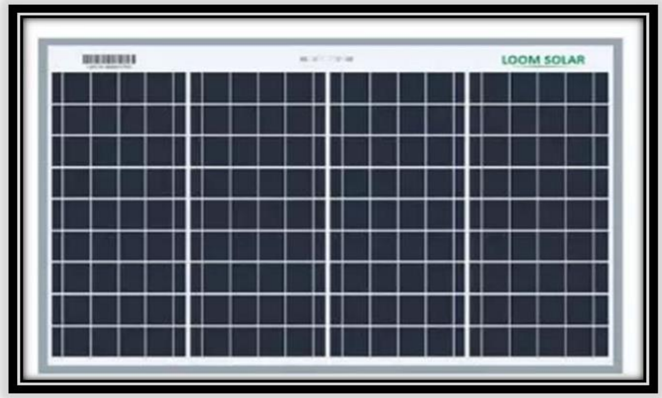


Fig.5 : Final Project Model

4.6 Major Components:

4.6.1 Solar Panel:-

Solar Panel is the best in class solar panels for home available in the market. The LOOM SOLAR's Solar Panel Price is lowest in market without compromising on the quality.

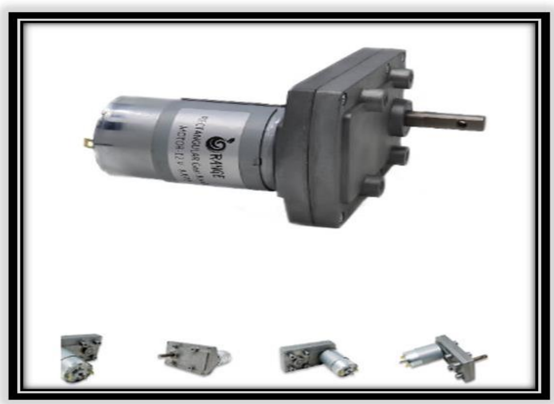


Photograph No 3: Solar Panel (LOOM SOLAR)

Loom is now India's most popular solar brand in India, The panels designed by loom solar are made to work for long years even in extreme weather conditions.

- Application: Perfect for charging Power Bank/Mobile/Small Battery up to 20AH.
- Reliable: Maximum defense against harsh environmental conditions is provided by white tempered glass (thickness 3.2/4.0 mm) and EVA resin with back sheet.
- Excellent Durability: The Loom Solar 40W's newly strengthened frame design enables it to withstand front loads of up to 6,000Pa and rear loads of up to 5,400Pa.

4.6.2 DC Geared Rectangular Motor (8RPM)):

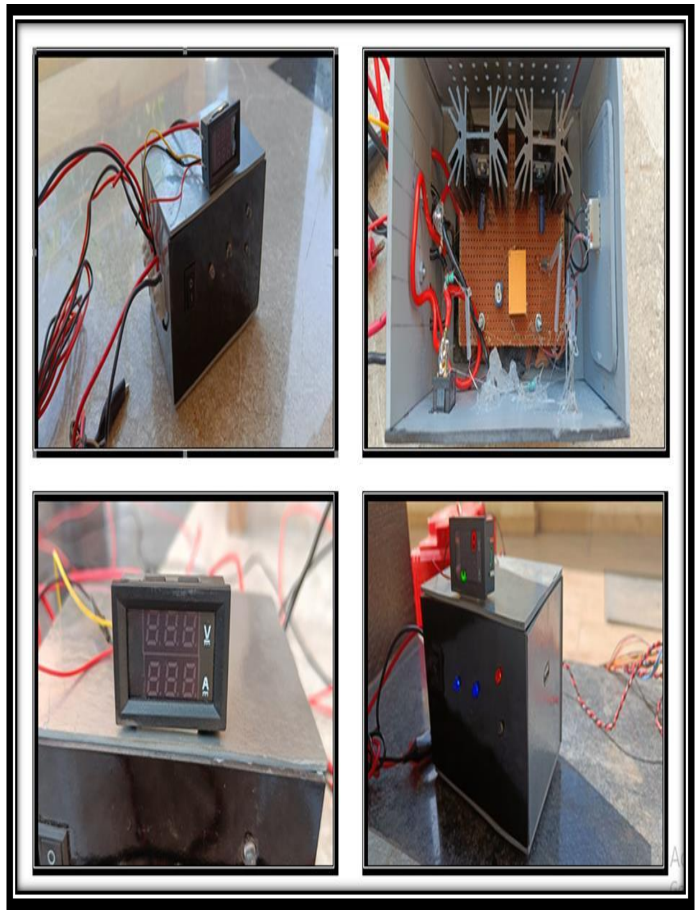


Photograph No.4: Geared Rectangle DC Motor(8 RPM)

This Orange TT555 12V 8RPM Rectangular gearbox DC motor has a gear ratio of 394K and a high torque rating of 5.066 N-m. The key characteristic of this motor is its 8mm-diameter, 27mm-long shaft with M4 tapping. The shaft of a market-available motor is typically 20 to 22 mm long; however, we have tailored the shaft of this motor to fit customer needs. Therefore, mounting a wheel or any other sort of connection on the shaft is too simple .For your convenience, we have designed this motor encoder equipped with a rear-shaft mount. If mounting the encoder is necessary for your application, it is simple to do.__The compatible OE-37 Hall Effect Encoder, which serves as a feedback encoder to offer real-time feedback of speed and rotating position of Motor, This motor can be used for a variety of things, including a central air conditioning valve, amusement equipment, coin-return machines, grills, and ovens. It can also be used for a peristaltic pump, an ATM bank automation system, office equipment, household appliances, medical equipment, and other things.

4.7 Power Supply & Charger for Controlling the Circuit:

- This Solar Charger contains inbuilt (5V/2A DC Charger Socket, Solar Power I/P & O/P, Battery Power I/P & O/P, 12V DC O/P, Voltage Controller, Battery Auto-Cut, Charging Indicators, Solar Indicators, Digital Display for Voltage & Current Indicator).
- It can be used for Power Supply, as like Motor Driver, etc.
- With this, we can give power to DC Appliances like DC (Motor, Fan, Light, Flood Lights, M/c's, etc).



Photograph No. 5: Power Supply & Charger for Controlling the Circuit

5. CALCULATIONS

1) LED TV-100 *1=100 W
2) LED Panel Light-12 * 10=120 W
3) Electric Fan- 80 *1= 80 W

Total= 300 W

Load / Power =300 W-----(a)

Inverter= 600 W---------(b)

C Current :-

$$P = V \times I$$

where, P= Power

V = Voltage

I = Current

300=12 X l

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$$I = \frac{300}{12}$$

I=25A

- Battery Size :-

$$\frac{W \times h}{V} = \frac{Total\ load\ \times Backup\ time\ (\ in\ hrs.)}{Battery\ Voltage}$$

$$6\ hrs. = \frac{300\ \times\ 6}{12} = 150\ Ah$$

$$4\ hrs. = \frac{300\ \times 4}{12} = 100\ Ah$$

$$3\ hrs. = \frac{300\ \times 3}{12} = 75\ Ah$$

$$2\ hrs. = \frac{300\ \times 2}{12} = 50\ Ah$$

- Battery Selected = *12V/ 60Ah*
- Battery Power = 12 x 60 = *720 W*
- Battery Backup = $\frac{Battery\,Wattage}{Total\ Load} = \frac{720}{300} = 2.4\ hours$
- Time required charging 100% battery:

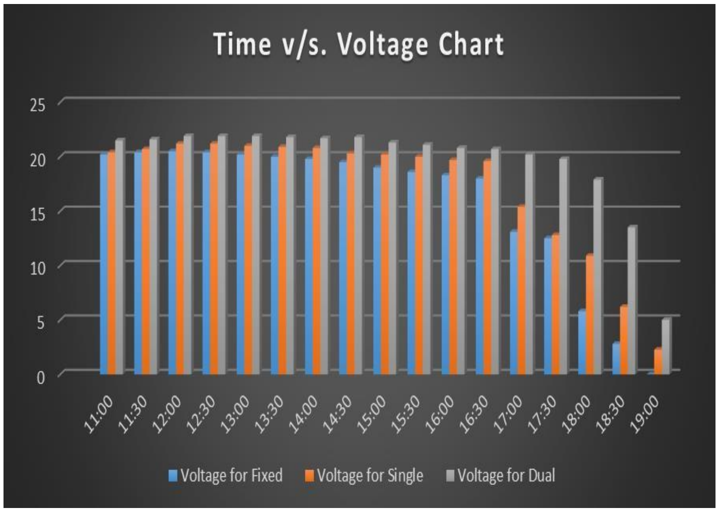
$$= \frac{Battery\ Capacity}{Power\ Generated} = \frac{720}{4.69} = 153.52\ Hr.s$$

6. OBSERVATIONS:

6.1 Voltages of all Modes:

Time (Hrs.)	Voltage for Fixed	Voltage for Single	Voltage for Dual
11:00	20.2	20.4	21.5
11:30	20.4	20.7	21.6
12:00	20.5	21.2	21.9
12:30	20.4	21.2	21.9
13:00	20.2	21	21.9
13:30	20	20.9	21.8
14:00	19.8	20.8	21.7
14:30	19.5	20.3	21.8
15:00	19	20.2	21.3
15:30	18.6	20	21.1
16:00	18.3	19.7	20.8
16:30	18	19.6	20.7
17:00	13.1	15.4	20.2
17:30	12.5	12.8	19.8
18:00	5.8	10.9	17.9
18:30	2.8	6.2	13.5
19:00	0	2.27	5.01

Table No.1: Voltages of all Modes with respect to Time

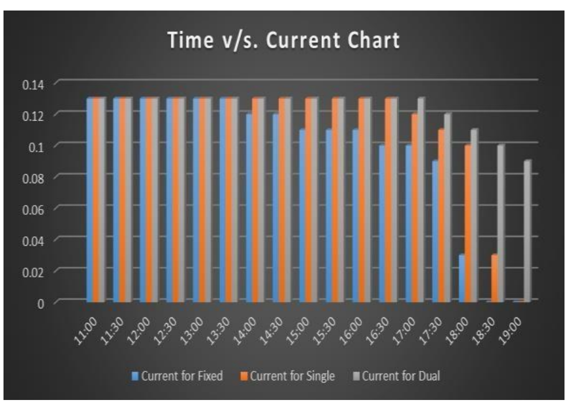


Graph No.1: Time v/s. Voltage chart

6.2 Currents of all Modes:

Time (Hrs.)	Current for Fixed	Current for Single	Current for Dual
11:00	0.13	0.13	0.13
11:30	0.13	0.13	0.13
12:00	0.13	0.13	0.13
12:30	0.13	0.13	0.13
13:00	0.13	0.13	0.13
13:30	0.13	0.13	0.13
14:00	0.12	0.13	0.13
14:30	0.12	0.13	0.13
15:00	0.11	0.13	0.13
15:30	0.11	0.13	0.13
16:00	0.11	0.13	0.13
16:30	0.1	0.13	0.13
17:00	0.1	0.12	0.13
17:30	0.09	0.11	0.12
18:00	0.03	0.1	0.11
18:30	0	0.03	0.1
19:00	0	0	0.09

Table No. 2: Currents of all Modes with respect to Time



Graph No. 2: Time v/s. Current Chart

7. TESTING:

The actual measurement is done by measuring instruments like,

- Rheostat
- Digital Voltmeter
- Digital Ammeter
- Multimeter

Connecting Wires

Photograph No. 6 : Testing Setup

The following photograph No. 7 shows measuring setup and reading.

Photograph No. 7: Taking Measurements and Readings

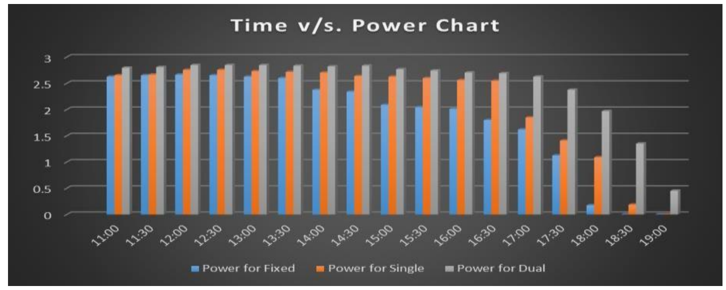
8. Result and Discussion:-

The effectiveness of various tracking systems and a suggested system in relation to various time periods throughout the day is examined.

Time (Hrs.)	Power for Fixed	Power for Single	Power for Dual
11:00	2.626	2.652	2.795
11:30	2.652	2.665	2.808
12:00	2.665	2.756	2.847
12:30	2.652	2.756	2.847
13:00	2.626	2.73	2.847
13:30	2.6	2.717	2.834
14:00	2.376	2.704	2.821
14:30	2.34	2.639	2.834
15:00	2.09	2.626	2.769
15:30	2.046	2.6	2.743
16:00	2.013	2.561	2.704
16:30	1.8	2.548	2.691
17:00	1.62	1.848	2.626
17:30	1.125	1.408	2.376
18:00	0.174	1.09	1.969
18:30	0	0.186	1.35
19:00	0	0	0.4509
Total Power Generated for 9 Hours	**31.095**	**36.512**	**42.3119**

Table No. 3: Powers of all Modes with respect to Time

Table No. 3 shows that list of solar panel tracking powers for various positions. It is abundantly clear that the suggested dual-axis tracker has a significant performance improvement, perfectly aligns with the direction of the sun, tracks the sun's movement, and does so in a more effective manner. The experimental findings unequivocally demonstrate the superiority of dual axis trackers over single-axis trackers and fixed systems. The table shows that the dual axis solar tracker's power capture is high throughout the entire observation period and that it maximizes the conversion of solar irradiance into electrical energy output As a result, it develops a method for the efficient use of solar energy and thereby aids in theconstruction of smart homes.

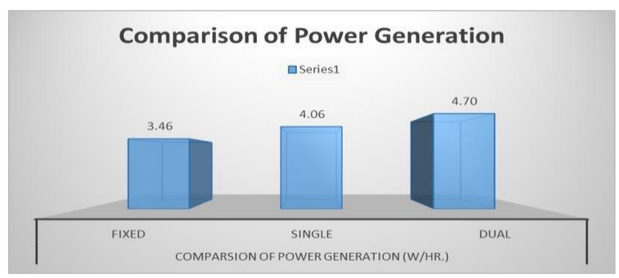


Graph No. 3: Time v/s. Power Chart

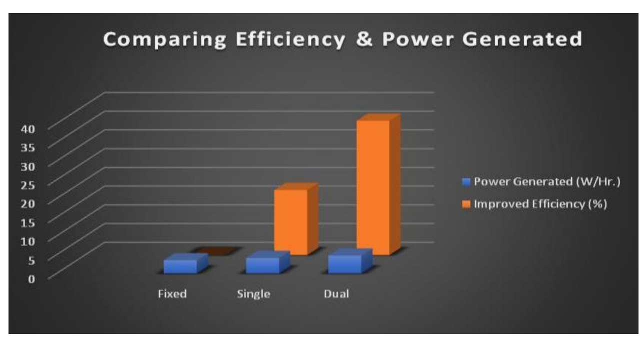
The above Graph (3) displays a bar chart comparing solar power using various tracking techniques. It is abundantly clear that the proposed method outperforms the current method in terms of output power.

Comparison of Power Generation (W/Hr.)		
Fixed	Single	Dual
3.46	4.06	4.70

Table No. 4: Comparison of Power Generation



Graph No.4: Comparison of Power Generation



Graph No. 5: Comparing Efficiency & Power Generation

Modes	Power Generated (W/Hr.)	Improved Efficiency (%)
Fixed	3.46	0
Single	4.06	17.34
Dual	4.70	35.84

Table No. 5: Comparison of Power Generation and efficiency.

Hence, Dual Axis has more Efficiency (35 %) than Single & Fixed Axis. And Power Generation of Dual Axis is more comparing to Single & Fixed Axis.

Photograph No. 8: Front View & Back View of Project Model

9. TOTAL COST OF PROJECT

SR. No.	TITLE	AMOUNT(Rs)
1	Fabrication	34745.6
2	Solar Charger Material	1993.25
3	Tracker Circuit Material	1778
Total		38516.85/- RS

Table No.1: Total Cost of Project

10. Conclusion:-

To increase the solar panel efficiency, a dual axis solar tracking solar panel powered by Arduino Nano has been developed and successfully put into use. Compared to the current Permanent Mount and Single axis Sun Tracker, the suggested Dual axis solar tracker is more efficient. With the aid of an Arduino Nano board, the proposed solar tracker that automatically tracks the sun to capture the greatest solar power was successfully completed [6]. The Arduino Nano board is easy to deploy and has cheap implementation costs for tracking solar power. The experimental system conclusively demonstrates that the suggested system successfully follows the sun in both favorable and unfavorable weather situations. When compared to the current system, the efficiency of the solar panel is significantly improved during various times of the day.

11. References:-

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