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Implementation of Dual Axis Solar Tracker using Servo Motor and PID Algorithm

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ABSTRACT - In the recent years, there has been an increase in the shift towards the usage of renewable energy sources. This is due to the fact that the increased use of fossil fuels for the purpose of energy generation has led to an increase in the environmental damage all over the world. The use of fossil fuels for the energy leads to a lot of pollution, such as air pollution due to burning of the fuels, water pollution due to dumping of waste by-products of the energy generation. This is the reason why the paradigm of renewable energy has been increasing in popularity in recent years. There has also been an acceleration of global warming and its effects that are visible quite clearly on the rising sea levels and the melting ice caps. Therefore, the governments have been providing incentives to shift to a much more renewable source of energy other than the fossil fuels that are predominant nowadays. This has led to increased applications of renewable energy that are being used by a large number of organizations and individuals. One of the most common forms of renewable energy sources is solar energy, as we know the harvesting of solar energy is purely based on the amount of solar radiation on that day. The solar radiation must be maximized as the solar energy harvesting is based upon the amount of sunlight received on a clear day. As the weather conditions are unexpected and can change any day, this creates very high variance in the amount of power generated. Adding to this, the solar cells need to be perfectly aligned to achieve maximum power generation. AS the sun keeps moving in the sky, it is impossible to manually manage it effectively. Therefore, this research article focuses on designing an effective mechanism for a dual axis rotation mechanism for solar cells. The approach effectively allows the orientation of the solar panels according to the sun automatically through the use of a combination of Light Dependent Resistors and servo motors.

I. INTRODUCTION

Human history has been effectively advanced on the basis of energy generation and consumption over the course of the human presence on the planet earth. Humans have been effectively utilizing various energy sources to power the growth of the civilizations. These advances have fuelled human curiosity and other endeavours. The endeavours have led to improved and highly comfortable life that is being led by us nowadays. There have been technological advancements that have been facilitated convenience. These conveniences come at a cost though, and the cost is energy. Energy has usually been utilized by early humans was organic energy by eating food and doing manual work.

The earliest form of energy was manual energy, up until the discovery of fire and fossil fuels. Fossil fuels are nothing but crude oil and their derivatives that have stored hydrocarbon energy that can be used for combustion. This rapidly increased the technological growth as the fossil fuels offered immense energy that could be effectively utilized. The fossil fuels have been in constant use ever since. Fossil fuels are being used for transportation, energy generation, major manufacturers and factories. It is the default form of energy in many applications.

In the recent years, there has been increased research being done on the paradigm of renewable sources of energy. This is largely due to the visible effects of the global warming and other environmental degradation that is happening all over the world. The citizens are becoming more and more aware in the recent years with increased interest in products and services that are environmentally friendly. The governments are also contributing to these approaches by providing tax breaks and exemptions on green alternatives.

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This is mostly due to the various climate change and environmental summits of world leaders across the globe, which is successful in providing an environmental impact perspective to the world leaders.

This increased influence and interest in the field of environmental improvements has led to various researches being performed to improve the paradigm of renewable energy. The most useful implementation in the renewable energy is the use of solar energy. Solar energy is the energy that is produced by the sun. The energy of the sun is in the form of radiation emitted by the surface of the sun. This energy can be converted into electrical energy through the use of photovoltaic cells. These cells utilize the incident radiation energy and convert it effectively into electricity. This electrical energy can then be stored in batteries to be utilized for implementation in various applications.

The solar energy is a form of free energy but it has some limitations. The conversion of the energy by the photovoltaic cells has very low efficiency. Even though this is increasing with every new generation thorough improvement in the hardware and the technology. One of the most important factors is that the energy conversion is dependent on the number of clear sky days in a month. This is due to the fact that the solar cells are very sensitive to light and the most intensive light produces the most efficient conversion into electrical power.

The solar cells are quite efficient in their conversion of the solar energy, and have been increasing in efficiency ever since. There have been major technological advancements that have driven the improvement in the energy conversion from the sunlight to electrical energy. The incident light rays on the solar panel are the source of the energy conversion. The electrical energy generated is directly proportional to the incident light rays on the solar panel. The light ray's incident exactly parallel on the solar panel produce the maximum electrical output from the solar panel.

As the angle of incidence decreases, the power output decreases exponentially. Most of the solar panels in widespread use nowadays are fixed installations. The sun is mobile across the sky which leads to inconsistencies in the power being produced throughout the day. The power also fluctuates between the seasons, where in the winter, when the sun makes a weeping angle across the sky. This low angle leads to an overall reduction in the output of the electrical energy produced that needs to be rectified. The presented technique has been implemented to effectively increase the output of the solar panels by maintaining a 90-degree angle with the sun rays effectively and automatically.

Scope of Project

The main objective is to identify and implement an improvement in the solar power generation. The scope of the project is restricted to implementing an effective and automatic mechanism for maximizing the solar yield for a solar panel by automatically adjusting the panel angle for the incident solar rays.

II. LITERATURE SURVEY

These are some literature surveys based on the research topic. They are as follows:

1. **Simple Design and Implementation of Solar tracking System Two Axis with Four Sensorsfor Baghdad city** by Falah I. Mustafa, Sarmid Shakir, Faiz F. Mustafa and others [1]

One of the most important goals for the purpose of achieving the maximum output form any system is to maximize the efficiency. Increasing efficiency can be highly useful in achieving an effective and useful improvement to generate maximum power from a solar cell. To maximize the output from a particular solar cell, the sunlight must be incident on the solar panel with a perpendicular angle. Thus, as the sun keeps moving in the sky, the angle of incidence keeps changing. The changing angle of incidence can reduce the efficiency of the solar power generation. Therefore, the solar panel must be positioned manually after constant intervals to achieve maximum efficiency which is not feasible. Therefore, the authors have proposed the use of a solar tracking system that rotates in two axis through the use of four sensors and motors to achieve maximum efficiency for solar power generation.

2. **An Automated Intelligent Solar Tracking Control System With Adaptive Algorithm for Different Weather Conditions** by NurzhigitKuttybay, Saad Mekhilef, Ahmet Saymbetov, MadiyarNurgaliyev[2]

The authors in this paper considers an intelligent automated solar tracking control system designed to increase the efficiency of solar energy production. The proposed method of detecting Cloudiness allows system to adapt to various weather conditions in real time by changing the angle of the solar panel. It is known that in case of

strong scattering of solar radiation in cloudy weather panels installed horizontally are more effective, rather than trackers which precisely oriented to the Sun. Proposed solar biaxial solar tracker equipped with two additional small solar modules. One of the modules is installed in a horizontal position, the second module is also a biaxial solar tracker. The algorithm for determining the position of the solar panel is based on known trajectory of the Sun during whole year saved in memory card and on monitoring the output currents of small solar panels built into the system. When cloudiness increases, the output current of a small solar horizontal module will exceed the current of the module oriented to the Sun. The proposed method exceeds energy collected by biaxial solar tracker by 18%.

3. **Design of ARM-Based Solar Tracking System** by Kang Mao, Fuxiang Liu, Ruijing Ji [3]
This paper presents a solar tracking system based on ARM, which mainly adopts the solar trajectory tracking mode, supplemented by the photoelectric sensor tracking mode according to the weather condition, and control the motor rotation to achieve all-time accurate solar tracking. The experimental results show that, the system performance is reliable, and all-weather tracking accuracy is maintained within 0.15 degrees. Therefore, the system can be widely used in solar photovoltaic power generation and lighting devices with solar energy utilization ratio improving greatly. The solar tracking system designed in this paper, using the ARM chip STM43F407ZGT6 as a microcontroller, adopts the solar trajectory tracking mode as the main method, then adopts photoelectric sensor tracking mode to realize accurate tracking according to the real-time weather conditions. In the actual test, the system is applied to the solar tracker, which runs stable and is able to achieve all-time accurate solar tracking with a tracking accuracy of 0.15°. Practice has proved that this system has reliable performance and wide practicability.

4. **Practical Implementation of Dual Axis Solar Power Tracking System** by Hend Abd El-monem Salama, Adel Taha Mohamed Taha [4]
This paper presents solar system development of solar system erected in lab. The system under study presents fixed solar module and it is converted into dual axis tracking module. A dual axis tracker has the ability to follow the sun vertically and horizontally through optimum light sensors connected to control system including Arduino program. Maximum Power Point Tracking (MPPT) solar model has been built associated the lowest cost mechanical system of tracking panel if compared with other mechanism methods of solar tracking systems. New model tracking system is analysed and compared with the old fixed system. Control unit is connected the solar system to permit the tracking solar panel operates individually or integrated to another solar panel. The results are investigated that ensures the MPPT has energy efficient and more reliability than modified fixed solar panel.

5. **Research and Design of Effective Positioning Algorithm for Solar Tracking System** by Katya Asparuhova Todor Djamiykov and Ivan Spasov[5]
The paper presents the research and experiments carried out in order to design an effective positioning algorithm for solar tracking system. The study deals with the method for controlling the driving mechanism of an experimental solar tracker device. An optimized algorithm for control of a solar tracker is proposed. Instead of moving it at equal time intervals, the tracker is moved in equal angular steps at different times of the day for each season. Compared to other solutions on the market, which usually use light sensors, the solution presented here avoids maintenance problems such as cleaning and calibration of light sensors, by using RTC for time acquisition and a microcontroller for coordinate determination. In this way the complexity of the solar tracker system is decreased and the price of the commercial device would be lower. It also allows for significant reduction in power consumption, because the driving mechanism is not forced to move continuously in order to find the point of maximum light intensity. Using just a single microcontroller, which can

6. **New Design for Solar Panel Tracking System Based on Solar Calculations** by Zuhal ER, and SelenMarangozoglu[6]
In order to obtain optimal yield, angle of incidence must be perpendicular to the surface. The motivation of this study is to design a solar tracking system. To move a panel through the direction of the Sun, it is crucial to define angles, caused by geometry of the Sun. This paper aimed, with new approach, the tracker design was made using by a controller. The new approach is design without any sensor to the determining of Sun's position. The calculations and the codes will be mentioned one by one in this study. The results are acceptable as expected for the location. Furthermore, the efficiency analysis can be achieved by carrying out

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experimental study and comparing them with conventional fixed/single axis panels. Therefore, other research studies are compared with the outputs and they illustrate that double axis tracking system are more efficient than the fixed and single axis tracking systems. It is inherent that theoretical calculations bolstered the new design for enhancing the usage of renewable sources, which is believed they will be more attractive in the future.

Present Scenario

The present systems that are utilized for the purpose of extracting the solar power for various activities in residential as well as the commercial establishments. These installations are usually a fixed in a particular orientation which reduces the power output significantly. This change is noticed as a significant reduction in the power generated in winters when it is cloudy and the sun time is reduced.

III. SYSTEM DEVELOPMENT

Project Specifications

There is a reduction in the power generated by the solar panels due to the panels being in a fixed position. As the sun takes a different position at different timings during the day, it becomes difficult to achieve maximum efficiency in fixed solar panel models. Therefore, an effective dual axis solar tracking system is being devised in this approach to achieve maximum efficiency.

Software: PC/ Laptop with internet enabled to interface Arduino Uno.

Platform / Language used: Arduino Uno/ C programming language.

IV. SYSTEM DESIGN

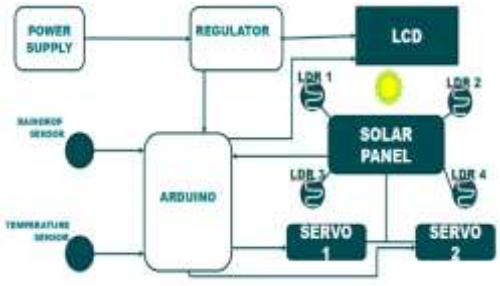

Fig 1 Block diagram of System

System Overview

The system is designed by following steps -

STEP 1: Building the Base. Attach the Base Servo arms inverted to the Base Mount for Left Right Movement.

STEP 2: Building the Interlock. The Interlock attachment will be placed on top of the Base Servo

STEP 3: The Solar Panel is to be placed on a mount and attached to the Centre Mount Frame which is attached to the Centre Servo for Up Down Movement.

STEP 4: Attach 4 LDR's to a circular plate with cross folds creating 4 segments. 1 for each LDR.

STEP 5: Attach the LDR plate to the Solar Panel Mount.

STEP 6: Make Circuit Connections according to the Simulated Circuit Design.

STEP 7: Code the device using Arduino IDE.

STEP 8: Indoor/ Outdoor Test with the Assembled Device. Record the Observations during different time intervals of the day.

STEP 9: Compare the Results

MODULE ALGORITHM

PID Algorithm for Solar Tracking:

Function: PID(T,V_A,H_A)

T=Temperature, V_A =Vertical Angle Value, H_A= Horizontal Angle Value

Output: revised V_A,H_A

1. Begin
2. SET M_{TMP} = Maximum Temperature
3. P_{VA}= (M_{TMP}*V_A) /T [P_{VA} =Vertical Proportional Angle]
4. P_{HA}= (M_{TMP}*H_A) /T [$P_{HA=}$ Horizontal Proportional Angle]
5. EV_A= T_{MP}(P_{VA}) → M_{TMP} [EV_A = Error Rate of Vertical Angle]
6. EH_A= T_{MP}(P_{HA}) → M_{TMP} [EH_A = Error Rate of Horizontal Angle]

7. **if** (EV_A !=0 AND EH_A !=0),**then**
8. IV_A =K ∫ EV_AdP_{VA} [K= constant]
9. IH_A =K ∫ EH_Ad P_{HA}
10. EIV_A= T_{MP}(I_{VA})→ M_{TMP} [EIV_A = Error Rate of Vertical Angle for Integration]
11. EIH_A = T_{MP} (I_{HA})→ M_{TMP} [EIH_A = Error Rate of Horizontal Angle for Integration]
12. **If** (EIH_A! = 0 AND EIV_A! = 0), **then**

$$DVA = K\frac{d(IVA)}{dt} DHA = K\frac{d(IHA)}{dt}$$

13. EDV_A= T_{MP}(DVA)→ M_{TMP} [EDV_A = Error Rate of Vertical Angle for Differentiation]
14. EDH_A= T_{MP}(DHA)→ M_{TMP} [EDH_A = Error Rate of Horizontal Angle for Differentiation
15. **if** (EDV_A! = 0 AND EDH_A! = 0), **then**PID(T,DV_A,DH_A)
16. **else**
17. V_A = DVA
18. H_A =DHA
19. **else**

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20. $V_A = IV_A$
21. $H_A = IH_A$
22. **else**
23. $V_A = P_{HA}$
24. $H_A = P_{VA}$
25. $ANGLE_{LIST}=\emptyset$
26. $ANGLE_{LIST[0]}=V_A$
27. $ANGLE_{LIST[1]} =H_A$
28. return $ANGLE_{LIST}$
29. End

Flowchart of Temperature sensing:

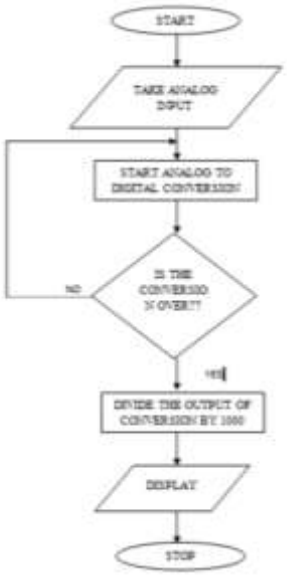

Figure 2: Temperature sensing flow chart.

Left/Right Movement

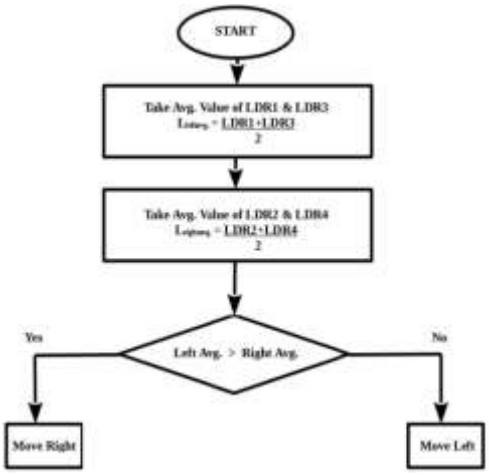

Figure 3: Left/Right Movement.

Up /Down Movement

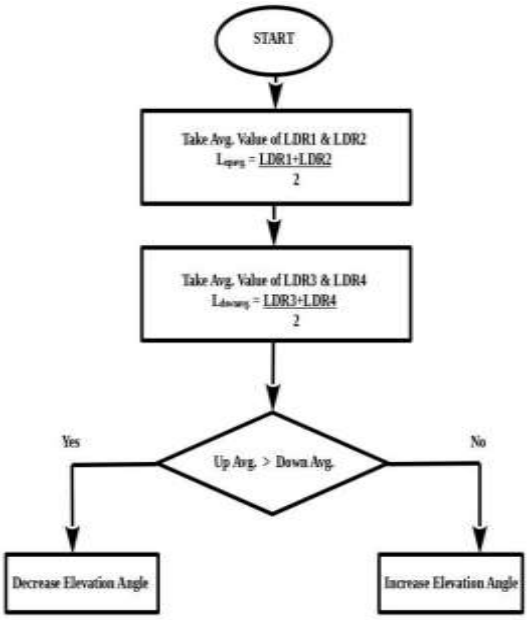

Figure 4: Up/Down movement flow chart

V. IMPLEMENTATION OF SYSTEM

Hardware components

Arduino

Description

• The UNO Based ESP8266 Nodemcu Development Board in the form of the Arduino UNO board format. This board is compatible with the Arduino IDE and with NodeMCU.

Features

• Based on ESP-8266EX.
• Arduino compatible, using Arduino IDE to program.
• Support OTA wireless upload.
• Onboard 5V 1A Switching Power Supply (highest input voltage 24V).
• The direct use of Arduino IDE development, the same operation with Arduino UNO

Solar Panel

Description

The 10W 12Volts 36-cell Solar Panel (41 x 30 cm) for DIY Projects is ready to use without requiring a frame or special modifications. We have chosen to sell these Polycrystalline solar cells because they are Laser cut to the proper size and encapsulated in the special sun and weather-resistant materials which give them unique characteristics.

Features

- 100% new high quality.
- 12 volt 10-watt polycrystalline solar panel USB charging
- High conversion speed, high-efficiency

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output.

- Excellent low light effect.
- Construction requires no frame or special modifications
- Ready to use, they require no frame or special modifications.

Servo Motor

Description

MG946R Metal Gear Digital High Torque Servo is an upgraded version of Torpor MG945. Its new PCB and IC control system which makes it more accurate. Its internal gearing and motor are also upgraded to improve dead bandwidth and centring.

Features

- Power Supply: Through External Adapter
- Servo arms & screws included and fit with Futaba servo arm
- It's universal "S" type connector that fits most receivers, including Futaba, JR, Hitec ,GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum.
- Upgraded servo gear set and shaft to aluminium 6061-T6. It is stronger and lighter than copper.

LDR

Description

The resistance of 20mm GL20528 Light Sensitive Photoresistor LDR changes with the change in the ambient light exposed on the surface of the sensor. As the light on the sensor increases then the resistance across the two leads decreases. Light Dependent Resistor is a type of photocell which finds excellent use in light sensing device application, whether it is automatic outdoor light ON/OFF switch or indoor automatic light switch; moreover, the 12mm LDR or photoresistor sensor works best in both light and dark regions.

Features

- Coated with epoxy
- Good reliability
- High sensitivity
- Small volume
- Fast response
- Good spectrum characteristic

Temperature Sensor

Description

The Analog Temperature Module is based on the thermistor (resistance increases with the ambient temperature changes) which sense the real-time temperature of the surrounding environment changes. Change in temperature data in analog form can be taken from this module on analog IO pins, then through any microcontroller, it can be easily converted and displayed in Celsius degrees or any other respective Unit.

Features

- Operating Voltage: 5v.
- Temperature measurement range : -55°C to 125°C.
- Measurement Accuracy : ±0.5°C.

Display

Description

This 1.3″ I2C OLED Display is an OLED monochrome 128×64 dot matrix display module with I2C Interface. It is perfect when you need an ultra-small display. Comparing to LCD, OLED screens are way more competitive, which has a number of advantages such as high brightness, self-emission, high contrast ratio, slim outline, wide viewing angle, wide temperature range, and low power consumption. It is compatible with any 3.3V-5V microcontroller, such as Arduino.

Features

- GND: Power ground
- VCC: Power positive
- SCL: Clock wire
- SDA: Data wire.

Moisture Sensor

Description: Seed Studio Grove Moisture Sensor

Features

- Soil moisture sensor based on soil resistivity measurement
- 2.0 cm x 6.0 cm grove module
- Grove compatible interface (u-blox version)
- Easy to use

Circuit Simulation

Circuit Simulation Platform: TinkerCAD
https://www.tinkercad.com/things/4WJlhZoHtsF-be-project-dual-axis-solar-tracker/editel

Circuit Simulation Components for TinkerCAD:

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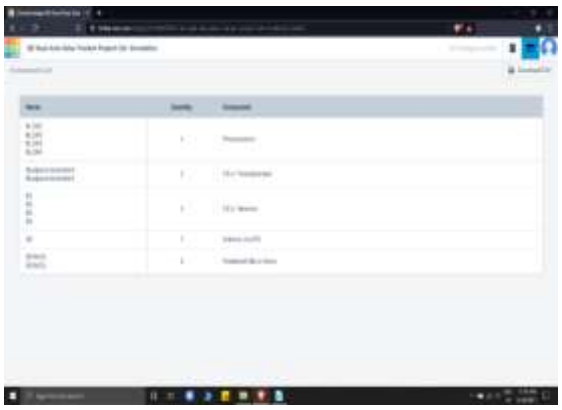
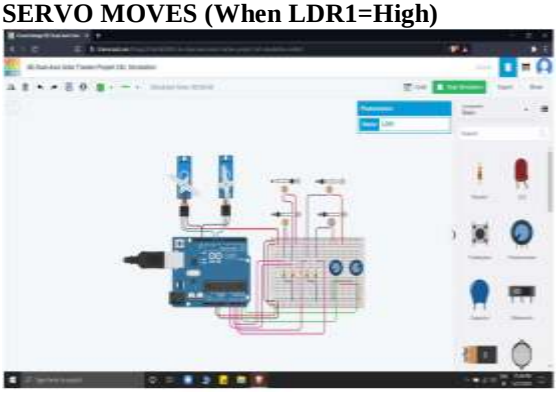


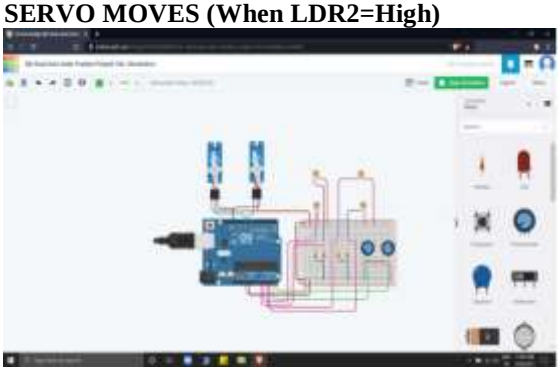
Circuit in OFF State

Circuit in ON State

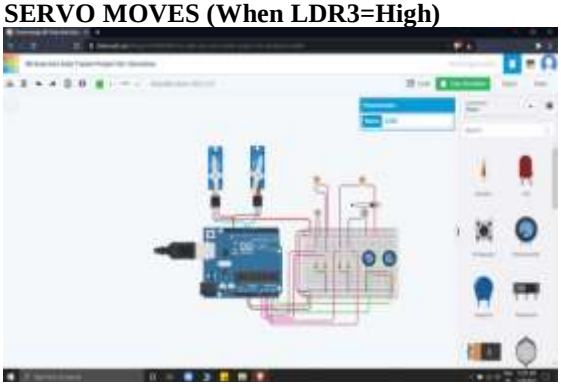
SERVO MOVES (When LDR1=High)



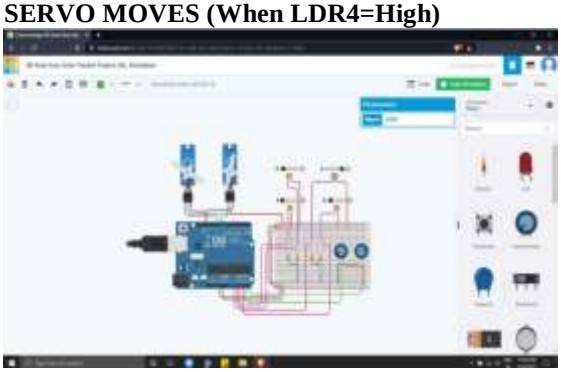
SERVO MOVES (When LDR2=High)



SERVO MOVES (When LDR3=High)



SERVO MOVES (When LDR4=High)



VI. CONCLUSION

In this report an effective technique for the purpose of maximizing the output of the solar cells have been discussed. The current techniques for the purpose of achieving an effective solar power generation have been designed to be fixed in one place. These approaches limit the output of the solar cell as they do not allow for the movement of the solar panel with the movement of the sun. This results in the solar cell generating peak power only for a short duration that can lead to very less power being generated overall. Therefore, this research proposes the use of an automatic mechanism to change the angle of incidence of the sun rays by changing the angle of the solar panel according to

the sunlight. The purpose of this mechanism to achieve an effective angle of 90 degrees of the solar panel to the sunlight to produce maximum power generation.

VII. FUTURE SCOPE

- To develop a reliable solar power generation improvement mechanism.
- The servo motor is used to change the angle of the solar panel with respect to the sunlight.
- Understood and operated this project by nontechnical users easily without the need for any advanced technical knowledge.
- To make it more convenient and easier for users to improve the solar power generation output effectively.

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