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Dual Axis Solar Tracking System

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ABSTRACT: The goal of this project was to develop a prototype of a solar tracking system, which is able to enhance the performance of the PV Solar panels. The operating principle of the device is to keep the photovoltaic modules constantly aligned with the sunbeams, which maximises the exposure of solar panel to the Sun's radiation. As a result, more output power can be produced by the solar panel.

Nowadays we have lots of power plants established on Solar and Wind Technology. Our project aims at Dual axis or Dual direction tracker. The Solar panel used in this system can adjust its direction both in X-Y co-ordinates. This helps better directivity with Sun rays, thus increasing the efficiency of the solar system.

The work of the project included hardware design and implementation, together with software programming for the microcontroller unit of the solar tracker. The system utilised an ATmega328P microcontroller to control motion of two servo motors, which rotate solar panel in two axes. The amount of rotation was determined by the microcontroller, based on inputs retrieved from four Light Dependent Resistors. i.e. LDR sensors located around four sides of solar panel.

KEYWORDS : PV Solar panels, Dual Axis, Servo motors, Lights sensors, LDR sensors

I. INTRODUCTION

With the unavoidable shortage of fossil fuel sources in the future, renewable types of energy have become a topic of interest for researchers, technicians, investors and decision makers all around the world. New types of energy that are getting attention include hydroelectricity, bioenergy, solar, wind and geothermal energy, tidal power and wave power. Because of their renewability, they are considered as favourable replacements for fossil fuel sources. Among those types of energy, solar photovoltaic (PV) energy is one of the most available resources.

Electrical energy from solar panels is derived by converting energy from the sun rays into electrical current. The main challenge is to maximize the capture of the sun rays upon the solar panels, which in turn maximizes the output of electricity. There are two possible ways to enhance output power from solar energy based systems. Either one can use an efficient material in the manufacturing of the photo voltaic cell or use a solar tracker to follow the sun.

This technology has been adopted more widely for residential use nowadays, thanks to research and development activities to improve solar cells' performance and lower the cost. According to International Energy Agency (IEA), worldwide PV capacity has grown at 49% per year on average since early 2000s. Solar PV energy is highly expected to become a major source of power in the future. However, despite the advantages, solar PV energy is still far from replacing traditional sources on the market. It is still a challenge to maximise power output of PV systems in areas that don't receive a large amount of solar radiation. We still need more advanced technologies from manufacturers to improve the capability of PV materials, but improvement of system design and module construction is a feasible approach to make solar PV power more efficient, thus being a reliable choice for customers. Aiming for that purpose, this project had been carried out to support the development of such promising technology. One of the main methods of increasing efficiency is to maximise the duration of exposure to the Sun. Tracking systems help achieve this by keeping PV solar panels aligned at the appropriate angle with the sun rays at any time. The goal of this project is to build a prototype of light tracking system at smaller scale, but the design can be applied for any solar energy system in practice. It is also expected from this project a quantitative measurement of how well tracking system performs compared to system with fixed mounting method.

For solar power calculations it is sufficient to consider the Earth as a simple sphere with a diameter of approximately 12800km. Points on the Earth's surface are defined in terms of longitude and latitude. The Earth rotates around its axis every 24 hours and orbits the sun every 365.25 days (Approximately). The axis of rotation is tilted at an angle of 23.45°

with respect to the plane of the orbit around the Sun. The axis is orientated so that it always points towards the Pole Star. This accounts for the seasons and changes in the length of day throughout the year. The angle between a line joining the centers of the Sun and the Earth and the equatorial plane is called the declination angle (δ). Because the axis of the Earth's rotation is always pointing to the Pole Star the declination angle changes as the Earth orbits the Sun. India lies in the Tropic of Cancer region. This makes it practically possible for implementing solar panel in our country compared to the countries located beyond 23.45° . The dual-axis solar tracker tracks the angular height position of the sun in addition to following the sun's east-west movement. The dual-axis works similar to single axis but it captures the solar energy more effectively by rotating its axis along vertical and horizontal axis.

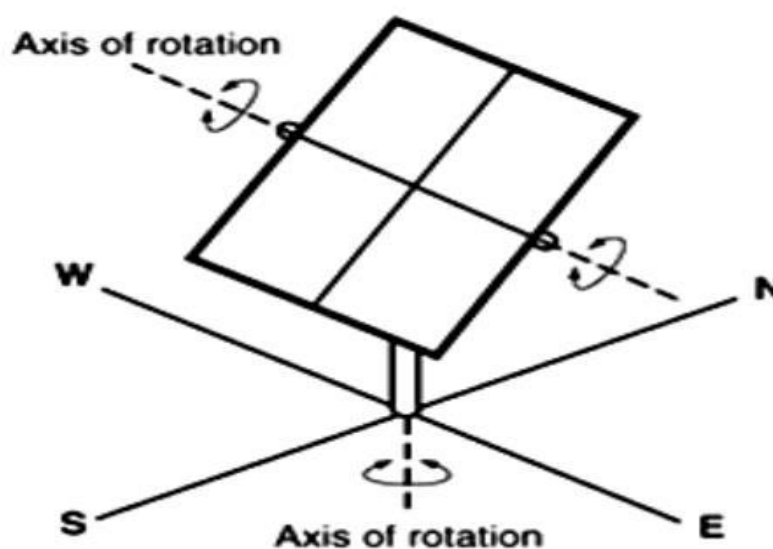


Fig 1. DUAL AXIS OF TRACKER

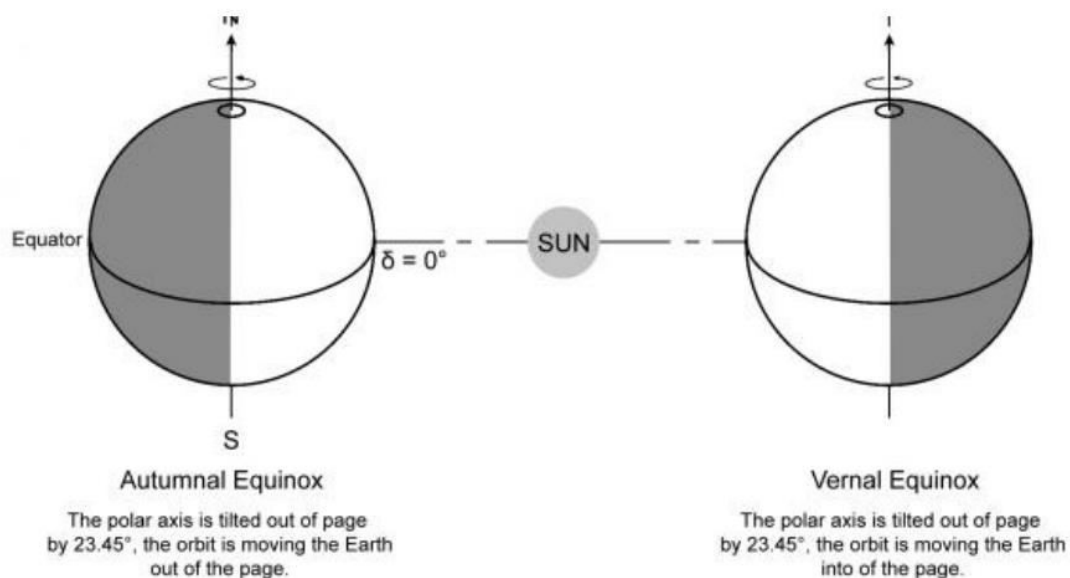


Fig 2. The autumnal and vernal winter equinoxes.

II. LITERATURE REVIEW/ MATERIALS & METHODS

Hossein Mousazadeh et Al. [(2011), Journal of Solar Energy Engineering, Vol.133] studied and investigated maximization of collected energy from an on-board PV array, on a solar assist plug-in hybrid electric tractor (SAPHT). Using four light dependent resistive sensors a suntracking system on a mobile structure was constructed and evaluated. The experimental tests using the sun-tracking system showed that 30% more energy was collected in comparison to that of the horizontally fixed mode.. Four LDR sensors were used to sense the direct beams of sun. Each pair of LDRs was separated by an obstruction as a shading device. A microcontroller based electronic drive board was used as an interface between the hardware and the software. For driving of each motor, a power MOSFET was used to control the actuators. The experimental results indicated that the designed system was very robust and effective.

K.S. Madhu et al., (2012) International Journal of Scientific & Engineering Research vol. 3, 2229–5518, states that a single axis tracker tracks the sun east to west, and a two-axis tracker tracks the daily east to west movement of the sun and the seasonal declination movement of the sun. Concentrates solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. PV converts light into electric current using the photoelectric effect. Solar power is the conversion of sunlight into electricity. Test results indicate that the increase in power efficiency of tracking solar plate in normal days is 26 to 38% compared to fixed plate. And during cloudy or rainy days it's varies at any level.

SPECIFICATIONS OF THE HARDWARE REQUIREMENT

FEATURES OF ARDUINO UNO

1) Microcontroller: ATMEGA 328P

The Atmel®picoPower®ATmega328/P is a low-power CMOS 8-bitmicrocontroller based on the AVR® enhanced RISC architecture.

FEATURES:

High Performance, Low Power Atmel®AVR® 8-Bit Microcontroller Family

- Advanced RISC Architecture
 - 131 Powerful Instructions
 - Most Single Clock Cycle Execution
 - 32 x 8 General Purpose Working Registers
 - Fully Static Operation
 - Up to 20 MIPS Throughput at 20MHz
 - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
 - 32KBytes of In-System Self-Programmable Flash program

Memory

- 1KBytes EEPROM
- 2KBytes Internal SRAM
- Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- Data Retention: 20 years at 85°C/100 years at 25°C(1)
- Optional Boot Code Section with Independent Lock Bits
- In-System Programming by On-chip Boot Program
- True Read-While-Write Operation
- Programming Lock for Software Security

2) Operating Voltage: 5v

3) Input Voltage (recommended): 7-12V

4) Input Voltage (limits): 6-20V

5) Digital I/O Pins: 14 (of which 6 provide PWM output)

6) Analog Input Pins: 6

7) DC Current per I/O Pin: 40 mA

8) DC Current for 3.3V Pin: 50 mA

9) Flash Memory: 32 KB of which 0.5 KB used by bootloader

10)SRAM: 2 KB (ATmega328)

11)EEPROM: 1 KB (ATmega328)

12)Clock Speed: 16 MHz

SOLAR PANEL

1) Maximum Voltage: 4volts (under load)

2) Maximum Voltage: 4.8volts (no load)

3) Rated Current: 100mA

4) Dimension: 6 cm (L) x 6 cm (W) x 0.25 cm (t)

5) Maximum Wattage: 0.5W

SERVO MOTOR

MODULATION ANALOG

Torque 4.8V :3.17 kg-cm

6.0V :4.10 kg-cm

Speed 4.8V :0.23 sec/60°

6.0V :0.19 sec/60°

Weight 37.2 g

Dimensions 39.9mm x 20.1mm x 36.1 mm

Motor Type 3 pole Ferrite

Gear Type Plastic

Rotation/Support Bushing

Operating angle 45 Deg.one side pulse travelling

400 µs

Pulse cycle 30 ms

Pulse width 500-300 µs

Connector Type J

LIGHT DEPENDENT RESISTOR

Photoresistor 5mm GL5516 LDR Photo Resistors Light-Dependent Resistor Model: GL5516

- Size: 5mm x 2mm

- Maximum Voltage: 150 Volt DC

- Maximum Wattage: 90mW

- Operating Temperature: (-30 to +70)°C

- Spectral Peak: 540nm

- Light Resistance (at 10 Lux): 5-10 kΩ

- Dark Resistance: 0.5 MΩ

- Response time: 20ms (Rise), 30ms (Down)

- Resistance Illumination: 4

III. METHODOLOGY AND WORKING PRINCIPAL

There are four Light Dependent Resistors (LDRs) which are placed on a common plate with solar panel. Light from a source i.e.(SUN) strikes on them by different amounts. Due to their inherent property of decreasing resistance with increasing incident light intensity, i.e. photoconductivity, the value of resistances of all the LDRs is not always same. Each LDR sends equivalent signal of their respective resistance value to the Microcontroller which is configured by required programming logic. The values are compared with each other by considering a particular LDR value as reference. One of the two dc servo motors is mechanically attached with the driving axle of the other one so that the former will move with rotation of the axle of latter one. The axle of the former servo motor is used to drive a solar panel. These two-servo motors are arranged in such a way that the solar panel can move along X-axis as well as Y-axis. The microcontroller sends appropriate signals to the servo motors based on the input signals received from the LDRs. One servo motor is used for tracking along x-axis and the other is for y-axis tracking. In this way the solar tracking system is designed.

Microcontroller does the comparison of signals received from LDRsensors and on the basis of stronger signal it is deciding rotation direction of stepper motors. Microcontroller is an intelligent device which functions on the basis of input that it

receives from the sensor thus activating motor driver circuit. The controller activates driver circuits and moves stepper motors to new positions where light falling on sensor pairs is same. If difference arises, then the motor moves the panel until the light falling on the sensor is same. Algorithm takes data from the sensors. Analog signals from sensors are converted to digital signals using analog to digital converter (ADC). This ADC module has to be present in the microcontroller or has to be added externally. Digitized signals are forwarded to microcontroller. The step angle and movement direction of stepper motors is calculated once the digitized signal is received. From the algorithm it is known that, microcontroller drives stepper motors only if sensor light sensing is not equal to each other. Throughout this process the PV panel is adjusted in a position for optimum power that is normal to the sun. Voltage regulation is necessary in case of solar panels as it keeps varying. An algorithm can be used after the solar panel which regulates voltage coming from solar panel. Power generated from solar panel is used to energize Tracker circuitry. This makes the project economical and cost effective too.

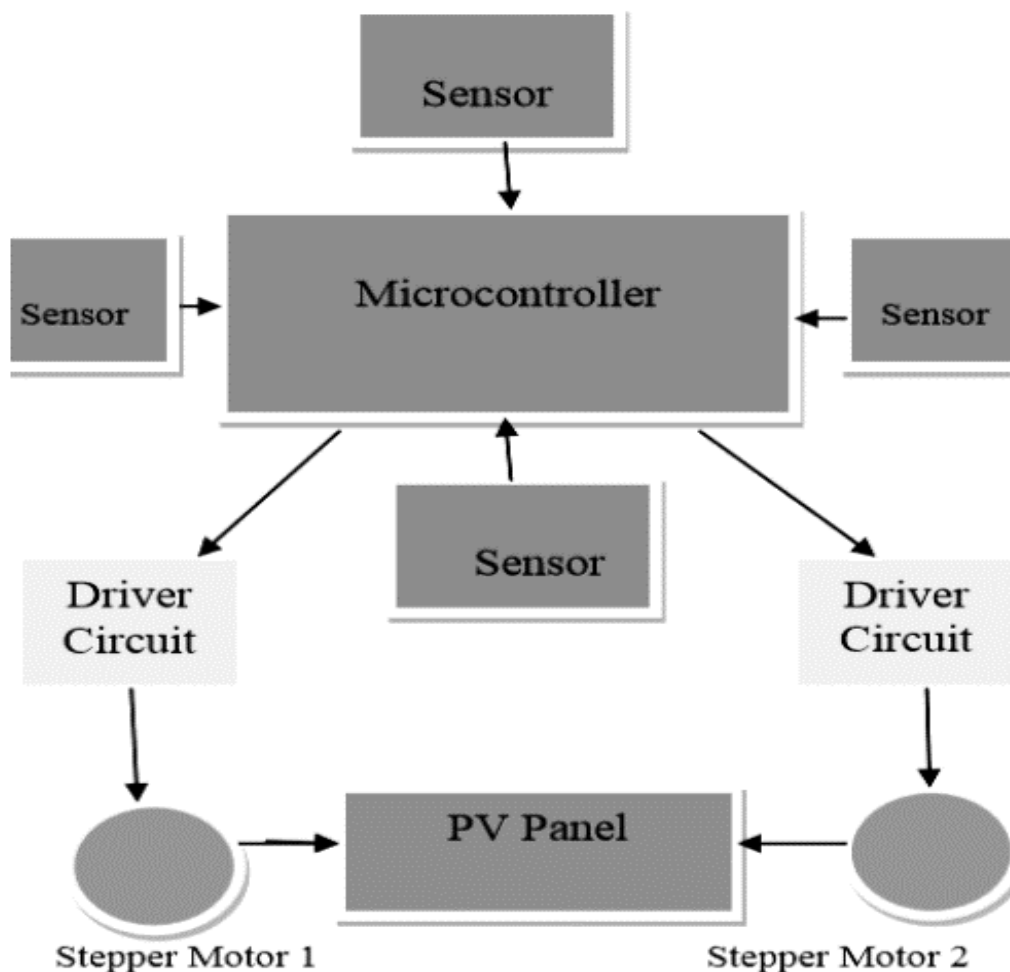


Fig 3. Block Diagram For Solar tracking system

IV. RESULTS

Average power obtained from solar panel is 0.88589 W for single axis solar tracker and is 1.3832 W for dual axis solar tracker. The efficiency is 69.85% for dual axis tracker and 44.74% for single axis tracker. It is observed that the dual axis tracking system provides more power output and presents an efficient system to collect solar energy which ensures more energy conversion than the single axis solar tracking system. The power outputs for dual axis tracker are higher than the single axis tracker. Maximum power outputs for both of trackers are obtained at 12.00pm. Power is increasing from 9.00am to 12.00pm and is decreasing from 12.00pm to 3pm. The peak value of power is achieved at 12.00pm which is 1.96974 W for dual axis tracker and 1.23375 W for single axis tracker. Dual axis tracker produces more power

as compared to the single axis tracker. The tracking mechanisms of dual axis and single axis solar tracker are capable of tracking the sun by consuming low power to run the servo motors. Dual axis solar tracker can track the sun according to its ray's incident on it. They can track sun in a region like ours more easily. But the structure and electrical circuit of dual axis solar tracker are little bit sensitive. That's why they could not withstand to strong wind. It is the main disadvantage of this type of tracking system.

Table No. 1. Result and calculations

Time of the day	Single Axis (Voltage)	Single Axis (Current)	Dual Axis (voltage)	Dual Axis (Current)	Power W Single axis	Power W Dual axis
9.00	9.52	0.076	10.05	0.105	0.72352	1.05525
9.30	9.6	0.083	10.18	0.119	0.7968	1.21142
10.00	9.7	0.089	10.37	0.123	0.8633	1.27551
10.30	9.73	0.092	10.46	0.127	0.89516	1.27551
11.00	9.75	0.096	10.49	0.134	0.936	1.40566
11.30	9.81	0.120	10.54	0.180	0.936	1.40566
12.00	9.87	0.125	10.59	0.186	1.1772	1.8972
12.30	9.79	0.109	10.50	0.162	1.23375	1.96974
1.00	9.71	0.102	10.34	0.157	1.06711	1.701
1.30	9.62	0.097	9.98	0.151	0.99042	1.62338
2.00	9.53	0.091	9.74	0.145	0.89723	1.4123
2.30	9.37	0.085	9.56	0.139	0.79645	1.32884
3.00	8.76	0.027	8.87	0.030	0.23652	0.2661



V. CONCLUSION

In this 21st century, as we build up our technology, population & growth, the energy consumption per capita increases exponentially, as well as our energy resources (e.g. fossils fuels) decrease rapidly. So, for sustainable development, we have to think alternative methods (utilization of renewable energy sources) in order to fulfil our energy demand. Initial cost of setups is higher since they would require moving parts. They also require maintenance cost. For the use in home, tracking is not a good solution for the power supply but in large industrial power generation systems they are very useful. For a poor country like us where energy crisis will never ends, these tracking systems may be an important aspect to make some more power from the sun and reduce our countries power crisis. Dual axis tracker is more efficient and gives more power than single axis tracker. Single axis tracker is cost effective. The complexity of hardware of dual axis tracker is more than single axis tracker. In this project, Dual Axis Solar Tracker, we've developed a demo model of solar tracker to track the maximum intensity point of light source so that the voltage given at that point by the solar panel is maximum. After a lot of trial and errors we've successfully completed our project and we are proud to invest some effort for our society. Now, like every other experiment, this project has couple of imperfections. (i) Our panel senses the light in a sensing zone, beyond which it fails to respond. (ii) If multiple sources of light (i.e. diffused light source) appear on panel, it calculates the vector sum of light sources & moves the panel in that point. This project was implemented with minimal resources.

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