Energy Efficient Solar Photovoltaic System

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ENERGY EFFICIENT SOLAR PHOTOVOLTAIC SYSTEM

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Abstract. Photovoltaic panels gather solar power and transform it into electricity. Solar cells are adjusted at a fixed angle making them less efficient. Solar cell's competence could be enhanced through designing a tracking system that automatically changes the spot of the PV panels in line with the movement of the sun. A solar tracking system traces both axis which is elevation and azimuth, a two-axis tracking system hold more solar intensity by tracing the motion of the sun in all flanks. The motive of project is to make our solar panels more efficient with the help of a tracking system including an Arduino controller, two motors with the arrangement of the gearbox mechanical structure rotate the solar cell next to sun, so that the sun's rays can stay aligned with the solar cell, all the sensors attached to adjacent sides of the module, using these sensors the system of tracking the sun makes a lot of sense and all helps to determine the precise spot of the Phoebus. The solar collector changes direction according to the intensity calculation. As the temperature of solar panels increase its overall efficiency decreases. Therefore, for this we add a device which is capable of cooling the panels. We add one more device to protect the battery from overcharging and from fluctuation of power generated by solar panels. We add IOT to determine the power output from solar and control the panel manually. It also helps to solve problem of asset management.

Keywords. PV-Photovoltaic, EMF – Electro Motive Force,

1. Introduction

Scientists define energy as ability to doing work. Modern civilization is possible because people have resources present in a limited quantity which once, they are depleted, they cannot be generated at the speed which can sustain its consumption rate. This type of energy sources has been depleted to a great extent due to their continuous exploitation and also there are not environment friendly. India pays for 7 percent of the overall global emission which is much lower than those of the US which produce up to 15 percent of overall global emission. In order to extent and detract the degradation of environment, the stimulation of the growth of green technologies and their adoption is necessary Among all the non-conventional source of energy, sun is the most bountiful sources of energy. A total of about 1.2* 10^5 TW of solar beam approaches to the ground from the sun. Willoughby Smith first explains "Effect of Light on Selenium during the passage of an Electric Current" in 1873 ,20th February issue of Nature. The first solid state photovoltaic cell was built by Charles Fritts in 1883 by coating the semiconductor selenium with a thin layer of gold to form the junctions, the device was only around 1 percent efficient. After four year three of their scientists, Calvin Fuller, Daryl Chapin and Gerald Pearson successfully developed a silicon photovoltaic panel. It had an electrical conversion efficiency of about 4 percent. Solar power has been increased more than 13-fold over the past six years from 2.6 GW in 2014 to 35 GW in June 2020. Till 30 June 2020 country's solar installed capacity was 35,739 MW. Electricity, solar energy production by the end of April 2019 to March 2020, the year amounted to 50.1 TWh, or 3.6 per cent of the total production (1,391 TWh).(The economic times, 2019).

As compared to fixed solar panels Arlikar et al. (2015) [13] showed that a 3D solar tracker based solar panel receives more energy. Solar trackers are the technology to increase the solar panel efficiency by placing the panels perpendicular with the sun. Solar trackers are driven by actuators or motors and keep the surface of solar panel perpendicular to the sun. Solar tracker was first introduced by Steve Hines to enhance the efficiency of any solar system. It traces the sun's position efficiently and keeps the solar PV module at such an angle for producing large amount of power. The tracker was capable of 52.78 percent power gains in comparison with a fixed mount panel. Tracking system is a complex system because it requires more site preparations, additional trenching for wiring and further, some of the classification system (Solar Energy Global, 2016), tracking systems are being used broadly as they have renovated the efficiency of energy extraction and in a way, has optimized the process.[1] The competence of single axis tracker from experiment was 25 % more than the fixed solar panel Experimental results showed that the overall efficiency of the dual axis tracker was improved by 43.65 percent neglecting the DC motor power consumption when solar panel is positioned perpendicularly to the sunlight. This paper is presenting both single and dual axis solar tracker model to track the sunlight providing the efficient way to enhance the power output and efficiency [2].

2. LITERATURE REVIEW

As per Praveen Kumar B et al. [3], the sun at an estimated temperature of 5800 K emits energy in huge amount by way of radiation, which reaches the earth. The sunlight is essentially split into two rays, the first of the direct beam and the second diffuse beam. The direct radiation, also known as beam-radiation of the sun, that does not scatter, producing a shadow. About 90% of the Sun's energy is in the form of radiation in the direct rays of the sun and the "diffuse sunlight" carries the residual. The diffuse radiation of the sunlight is the sun radiation that has been scattered (complete radiation on cloudy days). Insolation also called solar irradiation is a measure of solar energy received as radiation over a given surface area and recorded during a particular time. The unit recommended by the World Meteorological Organization is J/cm2 (joules per square centimeter) or MJ/m2 (mega joules per square meter) [4]. The average solar radiation received at the top of the Earth's atmosphere at any given time (about 52 weeks) is 1366 watts per square meter. As the augmentation of the angle between the optimal direction and the direction of the sun's beam increases, the insolation reduced in proportion to the cosine angle. This "projection" effect is the main reason why the polar regions of the Earth is cooler than the equatorial regions.[5] On an average the poles receive less insolation than does the equator, because on earth's poles surface are angled away from the Sun.

The number of emissions depends largely on the cosine angle of the incident known as the angle between the sun ray and the horizontal surface. The minimum incident angle enables maximum output. If there is a fixed panel the angle is max for the movement of the sun.[6]. Finster introduces first solar tracker in 1962, was totally mechanical. After a year, Sawavedra introduced an automated electronic control system, which was used to guide the Eppley pyrheliometer [7]. Anusha et al. [8] compare a fixed PV panel with a one-axis solar tracker focused on real-time clock (RTC) using an ARM processor. The tests were performed using a standard 6-day follow-up program. It demonstrates that the efficiency of solar tracking system increased by around 40% and the energy received from the sun was improved from morning 9.00AM to evening 6.00 PM. Dhanabal et al [9] compared the efficiency of static panels with single-axis tracking systems and dual axis tracking system. Readings are taken from 8 a.m. to 6 p.m. with a fixed panel, one axis tracker and a double axis tracker for everyone for an hour. The results show that the efficiency of a single-axis tracking system is 32.17% and that a two-axis tracking system is estimated to be 81.68%. Tiberiu tudorache et al [10] PV solar tracking panel and solar panel changes depending on power output and efficiency. The proposed device automatically discovers the optimum PV panel position with respect to the sun with a DC drive controlled by a smart drive unit that receives the input signal in the dedicated light senses of persistence. The solar PV tracking panel produced 57.55% more energy than the fixed power. Bione et al. [11] compare pulls systems driven by fixed, tracing, and tracing with PV torture. Results showed that with the given irradiance, flow rate of tap water was very different from each other. Fixed PV, PV with tracker and focus-tracking systems hit 4.9, 7.4 and 12.6m3 / day, respectively. Snehal et al. [12] raised the Field Programmable Gate Array (FPGA) Based Standalone Solar Tracking System sensor. Sun-based logic system is a seamless controller used in FPGA sensors, PV panel, stepper motor, and in-line interface. Xilinx ISE software is used to encode FLC tracking codes for the Sun. The results show that tracking works much better than scheduled panels. Charging control is an integral part of almost all power systems for battery chargers, air, hydro, fuel, or grid usage. Its purpose is to keep the battery well-fed and safe for a long time [13-20]. A charging controller is a controller that runs between solar panels and batteries. Solar system controls are designed to keep batteries charged without overcharging. Overcharging the battery can explode and the charging controller can help stop the battery from overcharging. The objectives of the paper are as follows:

A solar photovoltaic system which not only have a feature of rotating on dual axis to increase the efficiency of the whole system but also has parts for:

- Automatic control over the solar panel with the help of LUX VALUE CALCULATION nullifying the effects of weather conditions.
- Manual control over the system through the implementation of Internet of things (IOT) methods including the reset mode and asset management.
- Use of Piezoelectric generator to generate electricity during rain.
- Considering the problem of battery system inefficiency use of power controlling has been done in the proposed system.

3. PROPOSED METHOD

The efficiency of photovoltaic panel can be increase with help of dual axis solar tracker which help to maintain face of panel perpendicular to sun but there is also some problem related to it. First LDRs are light sensitive device which detect the moon light at night and turn on the tracking device, which start consuming the power from the battery. Second, the panel should come to its initial position (facing toward east) before sunset.

3.1 Automated Using Lux Value Calculation

All above problem's solve using lux value Calculation. We require component that are Arduino, Resistance. For first problem we calculate LUX value. Lux is a unit for measuring illuminance, the amount of light that hits an area, for a particular surface. Here in this module, we are calculating the LUX Value and fix an amount of light intensity above which the PV panel works and if it less than that then it gets switched off automatically. The moon light has low light intensity, so it doesn't work in moon light.

3.1.1 CIRCUIT: -

Connect one of the two LDR terminals to 5V and another to the GND using a single kilogram resistor. Connect the end of the wire to the analog pin A0 in Arduino and other to l K ohm resistor's non-grounded terminal in Arduino. When we increase the 1 K resistor to more value the value of lux value increase. The voltage output separator from the Arduino analog pin. The analog pin senses the voltage and delivers a certain analog value to the Arduino. We get a value depending upon how much the resistance of LDR decreases.

3.1.2 Formula for Calculation of Lux Value

RL=500/lux ---------- (3.1.1) V=5*(RL/(RL+R)) ------------- 3.1.2)

V=LDR_value*ADC_value --------(3.1.3) lux=(250/V)-50 ---------. (3.1.4)

where RL is the resistance of LDR, R is the resistance connected to LDR, LDR value is the Analog value read by micro-controller pin, ADC value is system voltage/ ADC 's Resolution, V is the analog measured voltage, lux is illumination calculated

3.2 RESET MODE

In this mode, we try to move the motor to its initial position at which PV panels facing toward east. At the time of sunset when sun starts moving to west, the intensity of light starts decreasing and resistance of LDR starts increasing. We set a value of light intensity for all four LDR when the light intensity of all four LDR goes below the set value, and the controller moves the panel facing east. So, Arduino moves the motor to its initial position facing the panel towards east.

3.2.1 CIRCUIT: -

Connect one of the two LDRs terminals to 5V and the other to the GND using a single ohm resistor. There are a total four LDRs in the circuit. For LDR1, LDR2, LDR3 and LDR4 connect one side of the cable to the analog pin A0, A1, A2 & A3 and another to 1K resistor's non-grounded terminal. The the output voltage output is supplied by the Arduino analog pin. The analog value changes according to LDR resistance.

3.3 HOW TO MOVE SOLAR PANEL ON DUAL AXIS?

To track the sun's location and adjust panels (moving the panels on dual axis) accordingly we need four LDRs here. These LDRs must relate to two motors to rotate the panels by sensing the position of the Phoebus. A pair of servo motors and two pairs of Light Dependent Resistors (LDRs) are used as sensors to track the exact position of the Sun. Arduino also use which work as a microcontroller. One pair of LDR felt the sun's position on the vertical axis on the east and west sides and on the other side on the horizontal axis on the north and south sides. The light-based antagonist (LDR) is a collateral that counteracts its decrease with increasing frequency light intensity. The main control unit of the entire system is Arduino controller. The direction of motion of both motors is determines from the output of the light comparison unit which comes from the input of the Arduino controller.

3.3.1 WORKING

We use LDR 1 and LDR 2 for movement of panel up down using motor 1 (M1) and LDR 3 & LDR 4 for movement of panel left and right using motor 2 (M2) we can see in the below figure (1). When the light intensity between LDR1 - LDR2 or LDR3 -LDR4 varies the motor move the panels and try to adjust the position until the intensity of LDR1 & LDR2 or LDR3 & LDR4 becomes equal. This helps us to keep our solar panel which is perpendicular to sun.

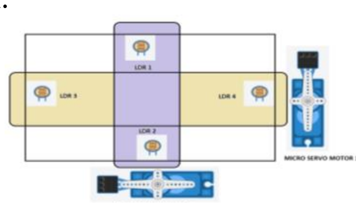

Figure 1 Controlling of Motor using LDR

3.3.2 PROPOSED MATHEMATICAL MODEL

On horizontal surface, irradiance is a function of the source tilt angle (Θ). Radiant power (Rp) described in eq (3.3.1) on the surface decreases with the increase in the tilt angle because as the tilt angle increases the effective area for the radiant flux reduces which is equivalent to AcosΘ as illustrated in Fig.2

$$Rp = Acos\Theta * \mathrm{Ee} \qquad \text{----------} \ (3.3.1)$$

Where Rp is radiant power, A is the area of the surface, and Ee is the radiant flux density (W m-2).

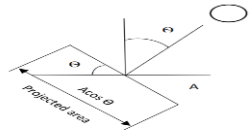

Figure 2 Irradiance on a Horizontal Surface

To maximize the power output, cosΘ should be 1 or Θ should be 0. This can be done by tracking the source (here sun) for its whole range of motion and maintain panel perpendicular to sun.

3.4 TEMPERATURE EFFECT ON SOLAR PANELS

As the temperature of the solar panel increases, its efficiency is completely reduced. Solar panels are tested at 25 ° C (77 ° F) so the temperature of the solar panel will usually be between 15 ° C and 35 ° C when solar cells will produce greater efficiency. However, solar panels can be as hot as 65 °C (149 ° F)

This problem is solved using the Thermo Electric Cooling Module. A thermoelectric cooling module (TEC) which acts as a small heat pump is an electronic semiconductor-based electronic device. The Peltier or Thermo electric cooler can be used as for cooling the solar panels or it can be used for generating electric current. If voltage supply is given to Peltier and attach the cold side to the panel & by attaching a small fan at hot side for heat sink, the temperature of panel decreases, and its efficiency increases This effect is called Peltier effect. Or if we attach the hot side with panel and use a small fan at the cool side, it can generate electric current (DC) which we can store in battery. This effect is called see beck effect This device will increase the overall efficiency of system. Peltier is small in size and it is economical. The conversion efficiency for see beck effect η in eqn (3.4.1) is defined as measurement of power generated by P_{TEG} and the inclusion of heat in a module Q_H

$$\eta = \frac{P_{TEG}}{Q_H} = \frac{P_{TEG}}{Q_C + P_{TEG}} --------- (3.4.1)$$

where Q_C is heat removed from cooled side.

3.5 PROTECTION OF BATTERY: -

Solar batteries are those battery which is capable to tolerate the fluctuation of voltage during day (charging) time and this battery is not charged using electricity. A normal battery charge with the help of invertor which supply constant Voltage to charge a battery and invertor stop the charging when battery get fully charged. Whereas dual axis solar tracking system generate 14Volts to 18 Volts during day. This fluctuation of voltage decreases the life span of battery and there is no device which prevent battery from overcharging. This problem is overcome with the help Buck Convertor which is also use in MPPT Solar Charge Controller. Buck converter has the ability to reduce the DC voltage by adjusting duty cycle (D) to switch the process with the help of a semiconductor

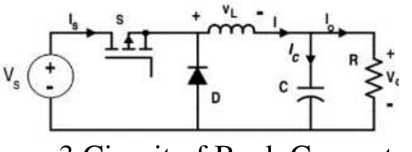

Figure 3 Circuit of Buck Convertor

Because of the high frequency of the square wave, the first transistor is turned on and the second transistor is turned off in buck converter. If the terminal gate of the first transistor exceeds the current through the magnetic field, it charges capacitor C, and provide to the load. Due to positive voltage across the cathode Schottky diode D1 get closed. Inductor L is the first current source. Current flows into the bucket operation when the first transistor is turned off by the control unit. The back EMF is generated collapsing field turn around the polarity of the voltage across the inductor & the magnetic field of the inductor is collapsed and. Current will flow in diode D2, load and diode D1 will turn on. Current decreases the discharge of inductor L. During the first transistor is in the one state the accumulator charge on the capacitor. Current flowing from the load and keep Vout reasonable during off time. As we already using Arduino as a microcontroller, we can track the output voltage and input voltage of buck convertor. We use a 12V relay, BD 139 transistor, Diode, Resistance and Variable resistance to make a circuit which helps to protect battery from overcharging

3.6 INTERNET OF THINGS (IOT)

By using Internet of Things (IOT) we can see the voltage generated by panel and control the tracking system. By connecting the dual axis solar tracker with our smart phones using IOT, system can be switched off any time when not in use. In solar plants where large number of solar panels are used for power generation and all the solar panel are connected in series, if any problem occurs in any panel, it is very difficult to find the defective one. With IOT we can-do real-time monitoring over the panel's system, through these we can find out faulty panels. A voltage sensor can be connected to every solar cell, which is further connected to Arduino Uno, wi-fi module and IOT. This makes it really easy to detect connection problems within the circuit and saves time.

4 SOFTWARE SIMULATION

Software Used: -TINKERCAD. WE divide the simulation in four modules. All the module are given below

Module 1: Automation of Solar Panels by LUX value calculation

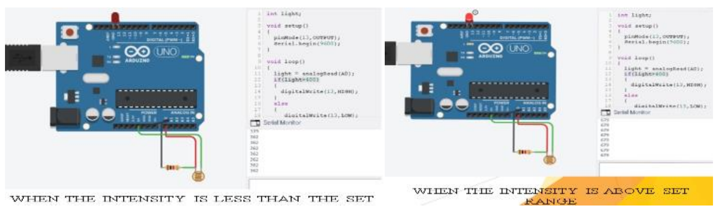

Figure 4.a and 4.b: Simulated Figure of Automation of Solar Panels by LUX value calculation

This simulation is example of LUX value calculation. In the above simulation we set a LUX value above which the LED glows. We see the LUX vale at right side of figure in serial monitor section.

Module 2: Movement Of Motor Using LDR

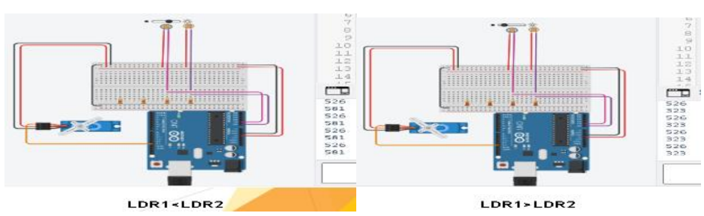

Figure 5.a and 5.b: Simulated Figure of Movement Of Motor Using LDR

In the above simulation figure, we can see when the LUX value of LDR1 is surpassing the value of LDR2, motor moves in anticlockwise direction & when the LUX value of LDR2 is surpassing the LDR1, motor moves in clockwise direction.

Module 3: Motor controlling for Dual Axis tracking

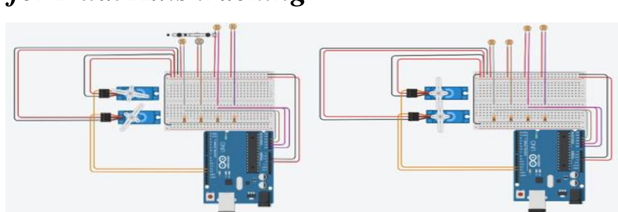

Figure 6.a and 6.b: Simulated Figure of Motor controlling for Dual Axis tracking

In the above Simulation Figure, we observe that when the light intensity of LDR varies the motor start moving and stops when the light intensity of LDRs become equal.

Module 4: Reset Mode

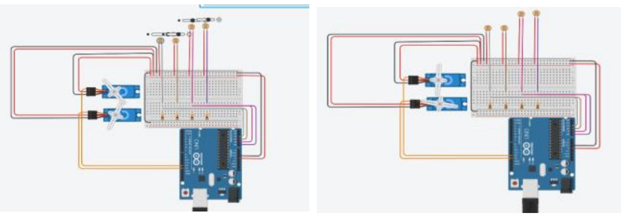

Figure 7.a and 7.b : Simulated Figure of Reset Mode

In the above simulated fig., we observe that when the LUX value is higher then set limit then the motor is moving and when the LUX value goes below the set limit it comes to its initial position.

5. CONCLUSION AND FUTURE SCOPE:

A solar photovoltaic system which not only have a feature of rotating on dual axis to increase the efficiency of the whole system but also has parts for automatic control over the solar panel with the help of Lux value calculation nullifying the effects of weather conditions is proposed. Manual control over the system through the implementation of Internet of things (IoT) methods including the reset mode and asset management are also presented. Here, use of Piezoelectric generator to generate electricity during rain is shown. Considering the problem of battery system inefficiency use of power controlling has been done in the proposed system. In future, energy efficiency improvement at semiconductor level can also be added into this system.

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Conflicts of interest/Competing interests: No
Availability of data and material: Data is available but will only be provided if mandatory.
Code availability: Code is available but will only be provided if mandatory.
Author's contribution: This research paperwork is purely contributed by the author.

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