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Design, Development and Testing of Tracking System for Solar Equipment

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Abstract— **Solar energy is rapidly gaining popularity as an important means of expanding renewable energy resources. As such, it is vital that those in engineering fields understand the technologies associated with it. The solar tracker ensures maximum intensity of sun rays hitting the surface of the panel from sun rise to sunset and can make best use of solar energy. The paper deals with the design, development and testing of tracking system for parabolic trough collector. It aims to develop efficient and effective tracking system.**

Keywords— **Solar tracking system, Photovoltaic cell, Parabolic trough, Solar energy**

I. Introduction

There can be no denying in the fact that solar energy is an effective source of power, one that is going to serve us for long. Solar energy is the cleanest source of energy and it is available in abundance. It can be easily harvested. Photovoltaic cells use sunlight and convert it directly to electricity without leaving any residual elements that can pollute the environment, and is therefore believed to be energy source that could be available to mankind. Maximum efficiency is possible when solar panels are held perpendicular to the sun rays where tracking comes into picture. Trackers are devices used to change the orientation of the PV panels towards the sun to capture maximum energy. There are different types of tracking systems such as active, passive and chronological tracking system. Active tracking system is the most preferred tracking system.

II. Literature Review

The Sun has been looked upon as an imperative source of energy. Solar energy is an eco-friendly resource as compared to its counterparts. The advancement of technology has out-turn foster techniques to utilize this energy into its own good use. Be it as thermal energy, electricity, fuel production and many more. Photovoltaic or concentrated solar power systems are operated to transfigure the solar power expropriated by the earth into electricity. Solar tracking device utilizes this expropriated solar power through the channel of photovoltaic arrays, an oriented scaffolding of photovoltaic cells.[1]

In this paper, a solar tracking system using Arduino is designed and built. This system collects free energy from the sun and stores it in the battery and then converts this energy to the respective alternating current. It makes the energy usable in normal homes as an independent power source. This system is designed to react to its environment in the shortest amount of time. Any errors at software and hardware will be controlled or eliminated. Our system is tested for its real-time responsiveness, reliability, stability and safety. Our system is designed to be resistant to weather, temperature and some minor mechanical stresses. An Arduino solar tracker was designed and constructed in the current work. LDR light sensors were used to sense the intensity of the solar light occurrence on the photo-voltaic cells panel.[2]

This paper deals with the efficiency of solar cell with and without tracking system. It also includes a proposed plan of simple dual dual axis tracking device which is based on servo motors which are in turn interfaced using Arduino microcontroller kit. The instructions to the servo motor comes from highly efficient light dependent resistors which are responsible for moment of PV panels towards maximum light intensity. The paper concludes that solar tracking system provides more effective method to track the solar insolation and provide economic consistency for generation of electric power.[3]

The aim of this research paper is to consume the maximum solar energy through solar panel. Power output from a solar cell will be maximum when it is facing the sun i.e., the angle between its surface and sun rays is 90 degrees. Solar tracking allows more energy to be produced because the solar array is able to remain aligned to the sun. The active sensors continuously monitor the sunlight and alternate the panel towards the direction where the intensity of sunlight is maximum. In this project, it's divided by two categories; hardware and software. In hardware part, 2 light dependent resistor (LDR) has been used to trace the synchronize of sunlight by detecting brightness level of sunlight. For rotation part, one standard servo motor has been selected. In software part, the code is constructed in C programming and inserted in Arduino. This project is designed for low power and portable application. [4]

In this research, the operation of a stepper motor mounted on a locally designed frame was controlled from a modified electronic circuit that causes the motor to half step instead of full step to achieve optimum solar energy collection. The modification on the control circuit of the Stepper Motor slightly altered its specifications to make it suitable for this application. The stepper motor with factory stepping angle of 1.8 degree was half-stepped to 0.9 degree to produce smaller rotations for precise positioning of payloads. In testing the stepper motor, a drive sequence digitally generated from a microcontroller was used to rotate the stepper motor through a half stepping sequence which resulted in a mean angle of 0.825 degree per-step. Hence this stepper motor can be found useful in tracking useful amount of solar energy for solar driers, solar reflectors and solar panel modules.[5]

In recent times the concentrated solar parabolic trough collector has been engrossed, with the advancement in solar energy absorption techniques which leads to various results. The absorber tube in the parabolic trough collector plays a vital role in handling various temperature range and absorption of solar radiation. The heat transfer fluid in the receiver tube makes a remarkable improvement in the thermal efficiency of the collector. The usage of molten salt for storing high temperature and also the treatment of Nano particles makes the parabolic trough collector a best operational thermal power plant. Most of the operational and under constructional solar thermal power plant in the world uses solar parabolic trough collector. Hence further researches on the parabolic trough collector make a more economical and ecofriendly thermal power plants.[6]

This paper presents the fuzzy logic control based solar tracking system using Arduino Uno. The proposed fuzzy logic controller has been implemented and tested using MATLAB. The above sun tracking power generation system has been tested in real time using Arduino Uno. The designed system increases the energy generation efficiency of the solar cells. Through the above research, we can conclude that the fuzzy logic controller increases the efficiency of the overall system. Stepper motor used for the direction control gives a precise position control and MPP is tracked efficiently throughout the day with the change in sun/ panel position. Fuzzy logic demonstrates efficient control, faster response and good conversion of human/ operator knowledge. It has also shown a better result over the conventional methods. Arduino Uno turned out to be an easy platform implement the control strategy.[7]

In this article, different types of sola tracking systems are summarized on their designs, thermal and electrical performances as well as the factors influencing the heat loss during operation. Based on ideas of energy collection and the sun tracking techniques, solar tracking can be divided into two categories viz. active types and passive types. These two major types of solar tracking can, in turn, be divided into many other different categories based on a number of parameters such as the number of axes, the tracking directions and methods among others. Each of these systems presents their own advantages; the double-axis solar tracking system provide better power stratifications while single axis processes are cheaper and less complex.[8]

III. Methodology

The idea behind the tracking system is the use of PV cells on both sides of the parabolic trough, choosing the size of the PV cell such that it shall be enough to produce the electricity to charge the battery which will drive the stepper motor over the span of 10 hours throughout the day. The same battery will run the Arduino board which is programmed to measure current and voltage output from attached PV cells and command the stepper motor to run screw jack and track the sun's path in the sky. The setup mainly consists a PV cell, stepper motor, Arduino board, voltage sensor, battery, and some software like Labview to write the program for the Arduino board.

The stepper motor is selected based on the torque required to turn the collar of the screw jack used for tracking. Total weight of 3 trough is 50 kg, pitch of screw jack is 1.2 cm, and collar radius of 6cm. Considering effort force and torque acting on collar, we are using stepper motor NEMA 23 as it has a vast range of torque holding, starting from 3.9 Kg.m to 18 Kg.m.

It has been decided that the entire system is going to run on 12V of potential difference. By considering system requirements, a 22000 mAh or Ah battery is chosen. This battery is charged for 10 hours by PV cells.

Four members of 5Watt 10 V solar panels can charge the 22000 mAh battery in 10 hours. So, considering the voltage and current, we required 4 PV cells.

We can measure a voltage up to 25 V with a 0-5 V analogue input range. This voltage sensor module also has simple screw connectors for connecting wires quickly and securely.

The Arduino programming is done to pick up changes in variations of voltage and run the entire tracking system according to the change in current and voltage.

As troughs are attached together, total weight of the assembly has to be considered for torque calculations. For handling total weight of troughs, a novel tracking mechanism has been devised, which consists of a screw jack, a V-link and a vertical link with notches. Screw jack is capable of holding and lifting extremely high loads, hence screw jack is introduced between motor and actuating mechanism. Current output variation is detected by sensors and signal is sent to Arduino to process. This signal is sent to motor controller which drives motor in required direction.

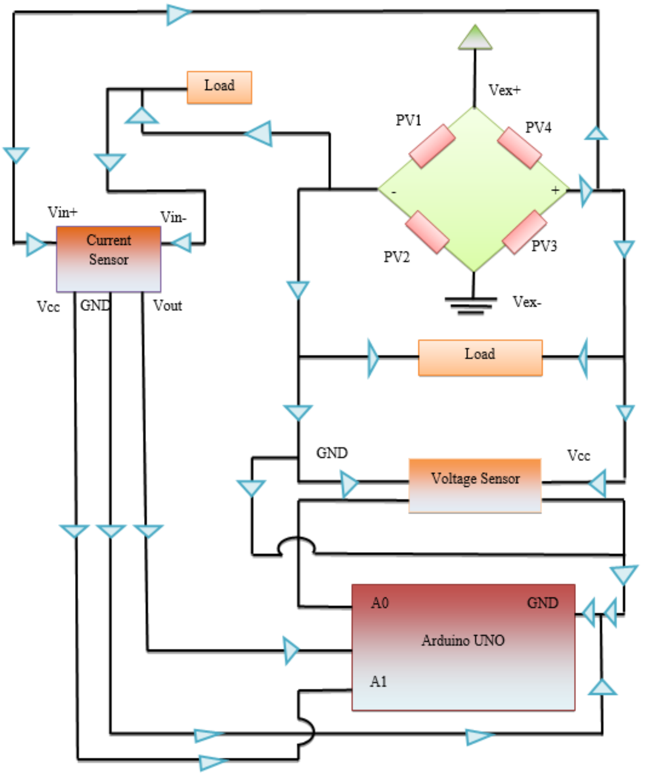

Fig. 1 Circuit Diagram for Tracking System

Total four PV cells are decided to use for the tracking system, two of them are going to be mounted on one side of the trough in series and another two on the other side of the trough in series, now these couple of PV cells on either side are in parallel to each other. Total current and voltage produced by PV cells on either side of the trough are measured by current and voltage sensors. But it has been observed that voltage variation is more distinct and easier to measure as compared to current measurement. So, voltage is measured from each side, if V1>V2 then the motor is made to run clockwise by receiving the command from the Arduino. If V1<V2 then the motor is made to run anti-clockwise and if V1=V2 then the motor will stop.
The idea behind this logic is, changing the position of the sun in the sky will produce different voltages in PV cells attached on either side of the trough until both sides are receiving beam radiations from the sun in a perpendicular direction, this itself means that trough has aligned itself in the directions perpendicular to the sun's rays and motor stops until the sun changes its position, changing the voltage in the PV cells which causes the motor to rotate in the clockwise or anticlockwise direction, changing position of the parabolic trough.
The solar tracking system rotates from east to west keeping the face of the solar panel towards the sun throughout the day. This is achieved using LDR and a motor interfaced with Arduino. Motor is connected to the screw jack. LDR is an active sensor which senses light intensity and its resistance increases with increase in the intensity of light. LDR acts as input, sensing the intensity of the sun. As the intensity falling on the west side LDR increases than the east side LDR (as the day progresses, the sun will be rotating towards west), the motor will rotate the panel towards west direction. An assembly language is utilized and saved into Arduino to achieve the rotation as stated earlier. The software part of the system can be split into two parts. The first part is initial positioning. Prior to powering up the system, the panel must be set towards the east, after the sunset and before the next sunrise. The second part deals with the actual movement of the panel, this is the heart of the program. Once the initial position of the panel is set, it is ready to align itself more preciously by continuously tracking the sunlight intensity. The compiled program controls the whole hardware operation.
Programming Code:
```
#include <Servo.h>
Servo myservo;
int initial_position = 90;
int LDR1 = A0;
int LDR2 = A1;
int error = 5;
int servopin = 9;
void setup()
{
  myservo.attach(servopin);
  pinMode(LDR1, INPUT);
  pinMode(LDR2, INPUT);
  myservo.write(initial_position);
  delay(2000);
}
void loop()
{
```

```
  int R1 = analogRead(LDR1);
  int R2 = analogRead(LDR2);
  int diff1 = abs(R1 - R2);
  int diff2 = abs(R2 - R1);
  if((diff1 <= error) || (diff2 <= error))  {
  } else {
  if(R1 > R2)
   {
     initial_position = --initial_position;
   }
  if(R1 < R2)
   {
    initial_position = ++initial_position;
   }
  }
  myservo.write(initial_position);
  delay(100);
}
```

Fig.2 Actual Mechanism and its Assembly

IV. Conclusion

Solar tracking systems which track changes in the sun's trajectory over the course of the day collect a far greater amount of solar energy, and therefore generate a significantly higher output power. The system developed has high load carrying capacity of screw jack, so multiple troughs in series can be driven. System is sensor based so high accuracy is achieved.

The conventional active tracking system is effective but delicate, susceptible to damage because of changes in atmospheric conditions, and its life expectancy is less. Apart from that, it consumes electricity continuously. The above-discussed system uses PV cells for the generation of electricity needed for running the tracking system and at the same time, it provides the base for tracking as well based on voltage change. The entire proposed system is comparatively cheaper and easy to install and therefore can be used in different solar tracking systems apart from parabolic trough collectors, this system is useful in all the collectors who uses the single axial tracking system.

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