Two Axis Solar Tracker Design and Implementation

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Abstract

The energy extracted from a solar photovoltaic (PV) panel depends on solar insolation. For extraction of maximum energy from the sun, the plane of PV panel should always be normal to the incident solar rays. The seasonal movement of the earth affects the radiation intensity received on the PV panel. Sun trackers move the PV panel to follow the sun trajectories and keep the orientation of the solar panel at an optimal tilt angle. Energy efficiency of a solar PV panel can be substantially improved by using solar tracking systems. In this work, two axis solar tracking system has been designed and realized by using LDR sensors and DC motors with gear arrangements. The tracking (azimuth angle and altitude angle) has been implemented via microcontroller based control logic. Important points of this design are using minimum energy while tracking, stability of trajectory, maximum energy efficiency with gear arrangements and being cheaper than the other tracker systems.

1. Introduction

The green energy, also called renewable energy, has gained much attention nowadays. Some renewable energy types are solar energy, hydro potential energy, wind energy, biomass energy, terrestrial heat, temperature difference of sea, sea waves, morning and evening tides, etc [1, 2]. Among these, solar energy is one of the most efficacious resources that can be used. However, so far the efficiency of generating electric energy from solar radiation is relatively low. Thus, increasing the efficiency of generating electric energy from the solar radiation becomes very important issue. Since PV systems were built at fixed position in the past, they cannot track the sun. Therefore their efficiency is low. The average solar energy intercepted by a fixed PV panel is constant. More energy can be extracted in a day, if the PV panel is installed on solar trackers. Different ways have been experimented for tracking the sun. One of these methods is freon gas system. This system tracks the sun in one direction (East-West), it is effected by weather conditions (especially on rainy days) and it is also expensive. Because of the above reasons, it has not preferred [3]. Another alternative is to have a database of the sun's position according to the region and seasons where the tracker will be implemented. Annual positions of the sun are recorded to database of microcontroller. Recorded data sets the position of tracker round the clock. However, this system has to be put up in east-west direction. If there is any error in put up direction, the system will not function properly. Usually such systems are expensive and complex based on the requirement for the database storage media and clock accuracy.

The two axis solar tracker sense the direct solar radiations falling on photo-sensors as a feedback signals to ensure that the PV panel is tracking the sun all the time, keep the PV panel at a right angle to the sun's rays for getting the maximum solar insolation. In this work, two axis solar tracker system has been designed and implemented by using four LDRs and two DC motors with gear arrangements. The tracker's control algorithm has been implemented via Atmega328p microcontroller on a simple and cheap mechanical structure.

2. Description of Two Axis Solar Tracker System

2.1. Schematic Arrangement

Two-axis tracking system changes both azimuth (horizontal) and altitude (vertical) degrees of solar panel. Schematic block diagram of the proposed solar tracker is shown in Fig. 1. Four LDR sensors and a trimpot are used to feedback from DC motors. Trimpot has been mounted to shaft of DC motor 1. LDR1 and LDR2, LDR3 and LDR4 are taken as pairs (please see Fig. 5). If one of the LDR in a pair gets more light intensity than the other, a difference will occur on node voltages sent to the respective ADC channels of the microcontroller. The microcontroller calculates those node voltage differences and compares them with the respective set values. After that it generates necessary logic signals to actuate the DC motors in

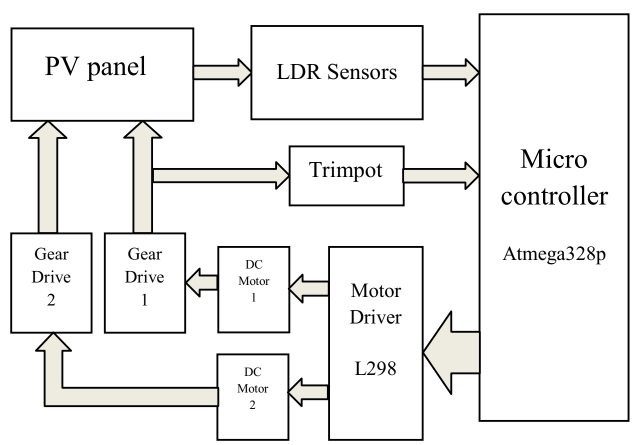

Fig. 1. Block diagram of the solar tracker

such a directions that light intensities on LDRs in each pair are equal. The voltage value coming through trimpot is compared with predefined value to determine the position of tracker. LDR pairs have been fixed to reciprocal positions on the border of PV panel (see Figure 5). If LDR pairs are illuminated equally by the sun, the analog voltage signals received by the ADC channel of the microcontroller will have equal values and microcontroller will not generate any logic signal to actuate the motors. L298 IC having two channels has been used to drive the DC motors. DC motors with gear arrangements have been selected since they are cheaper than stepper and servo motors. Motors which drive the PV panel in azimuth and altitude positions (motor 2 and motor 1) are seen in Fig. 2. DC motors with gear arrangements have been used to achieve the desired speed in moving the PV panel in azimuth and altitude positions. The most important effect of using DC motors with gear mechanism in two axis tracker system is getting mechanical stability of PV panel without spending much power for DC motors. When the panel is not desired to move, the DC motors are not driven and PV panel is kept in stable position due to the mechanical lock mechanism in the gear systems of DC motors. So, the electrical efficiency of solar panel system has also been increased in this manner.

2.2. Sensor and Trimpot System

Light dependent resistor (LDR) is a resistor whose resistance decreases with the increase of light intensity falling onto it. If light falling on the device is of high frequency, photons absorbed by the semiconductor gives enough energy to bound electrons to jump into the conduction band. The resulting free electron conducts electricity, thereby lowering the resistance [4]. To track the sun, an electro-optical sensors are needed. Using six LDRs and their algorithm for the sun tracking is based on utilization of four LDRs for tracking the azimuth and altitude angle and the other two for sensing the day and night [5]. In our work, only four LDRs have been used. The sensors are used both for tracking on azimuth and altitude angle and sensing the day and night. These sensors are placed on the frame of the PV panel by 90° apart. Each LDR is connected in series with a resistor of 220Ω and a Wheatstone bridge circuit is formed using all four LDRs and four resistors. Wheatstone bridge and trimpot circuit diagram for the sensor system is illustrated in Fig. 3. A voltage divider circuit is formed at the node 1, 2, 3 and 4 between LDR and a series resistor of 220Ω. The voltage is measured at the nodes as input to the microcontroller. The ADC channel 0, 1, 2 and 3 of ATmega328p microcontroller is connected to the node 1, 2, 3 and 4 of the Wheatstone bridge circuit respectively to receive the voltage signals coming through LDR1, LDR2, LDR3 and LDR4. The microcontroller calculates the difference of voltage signals received at ADC

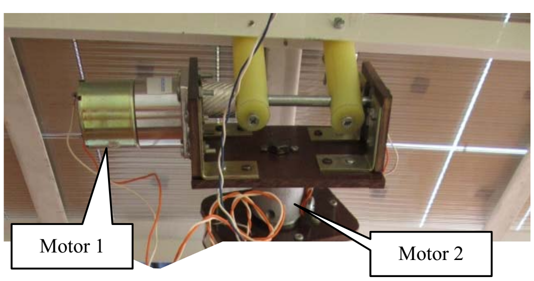

Fig. 2. Motors driving the tracker mechanically

channels 0 and 1 for the altitude angle tracking and the difference of voltage signals received at ADC channels 2 and 3 for the azimuth angle tracking. If the difference of those signals is greater or less than a predefined value, microcontroller will send logic signal to the H-bridge (IC L298) to drive the DC motors. The trimpot mounted on the shaft of motor 1 feeds back a voltage value that is used to determine the position of the DC motor 1. This voltage is also used to determine the initial position of the PV panel. If the value of the voltage coming through this trimpot is outside of the permissible region, DC motor 1 is stopped for safety of the system. Finding the initial position of our solar tracker by itself is the most important difference from the other tracker systems. After sunset when the weather turned dark, all LDRs sense night, trimpot reports the position of DC motor 1. Microcontroller analyzes the data and generates a logic signal to drive the DC motor 1 to turn back the PV panel to its initial position. The initial position of the PV panel is parallel to horizontal plane. Putting the PV panel into its initial position prevents it turning back to sun's rays in the morning times. The ADC channel 4 of the microcontroller is connected to adjustable leg of trimpot.

2.3. Two Axis Solar Tracker Controller

The control circuit is powered by a 12V battery and this battery is charged by the PV panel. Thus, tracker system does not need any external power supply. Output voltage of PV cells changes with the sun's radiation therefore; the output voltage has been regulated with LM317T IC to charge the battery (please see Fig. 4). The DC motors can turn either in clockwise or counter clockwise direction depending upon the sequence of the logic signal sent to L298 driver IC. Two logic ports of the microcontroller are used for each channel of L298 IC DC motor drive. The sequence of the logic signal depends on the difference of light intensity on the LDR sensors. DC motors can move together in the system. One of the motors does not wait other. They can be driven in the same time.

2.4. Software Description

Arduino IDE has been used to obtain the operation code. The programmer card for the same IDE is used to upload the machine code into the microcontroller. The code has been also simulated in PROTEUS Professional Simulator to see if it works properly. The algorithm of the written code is given as steps in what follows.

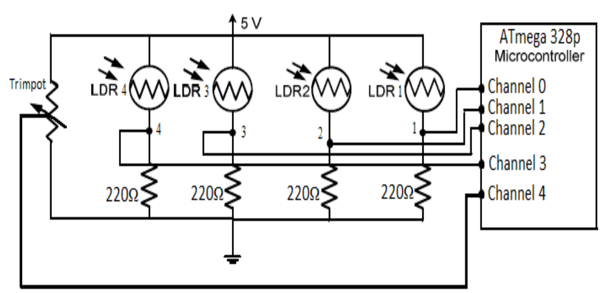

Fig. 3. Wheatstone bridge circuit for the sensor and trimpot system

Step 1) Read all analog voltages coming from all ADC channels.

Step 2) If any voltage coming from a LDR is lower than 0.025 volt, then move motor 1 into its initial position and go to step 1, otherwise go to step 3.
Step 3) Check $(V_{LDR1}\text{-}V_{LDR2})>V_D$. If it is true, go to step 4, otherwise go to step 13.
Step 4) Check the voltage coming from the trimpot. If it is outside of the permissible region then stop motor 1 and go to step 1, otherwise go to step 5.
Step 5) Check $(V_{LDR1}\text{-}V_{LDR2})>V_D$ again. If it is true, go to step 6, otherwise go to step 9.
Step 6) Move motor 1 in backward direction.
Step 7) Check $(V_{LDR1}\text{-}V_{LDR2})<V_D$. If it is not true, then go to step 6. If it is true, go to step 8
Step 8) Stop motor 1 and got to step 1.
Step 9) Check $(V_{LDR2}\text{-}V_{LDR1})>V_D$. If it is true, go to step 10, otherwise go to step 12.
Step 10) Move motor 1 in forward direction.
Step 11) Check $(V_{LDR2}\text{-}V_{LDR1})<V_D$. If it is not true, then go to step 10. If it is true go to step 12.
Step 12) Stop motor 1, and go to step 1.
Step 13) Check $(V_{LDR3}\text{-}V_{LDR4})>V_D$. If it is true, go to step 14, otherwise go to step 16
Step 14) Move motor 2 in clockwise direction.
Step 15) Check $(V_{LDR3}\text{-}V_{LDR4})<V_D$. If it is not true, go to step 14, if it is true, stop motor 2 and go to step 1.
Step 16) Check $(V_{LDR4}\text{-}V_{LDR3})>V_D$. If it is true, go to step 17, otherwise go to step 19.
Step 17) Move motor 2 in counterclockwise direction.
Step 18) Check $(V_{LDR4}\text{-}V_{LDR3})<V_D$. If it is not true, go to step 17. If it is true, go to step 19
Step 19) Stop motor 2 and, go to step 1.

V_{LDR1}, V_{LDR2}, V_{LDR3} and V_{LDR4} that are mentioned in the above algorithm represent the voltage values coming through LDR1, LDR2, LDR3 and LDR4, respectively. The algorithm starts with reading all voltages coming through the ADC channels. If at least one of the voltages coming through LDRs is lower than a predefined value, it means that the weather is turned dark. It is therefore motor1 is put into its initial position (PV panel is parallel to horizontal plane). In step 4, the voltage value coming from the trimpot is checked against the permissible region. If this value is outside of the permissible region, motor 1 is stopped just not to destroy PV panel mechanically (otherwise the PV panel can run into the pole that supports the PV panel

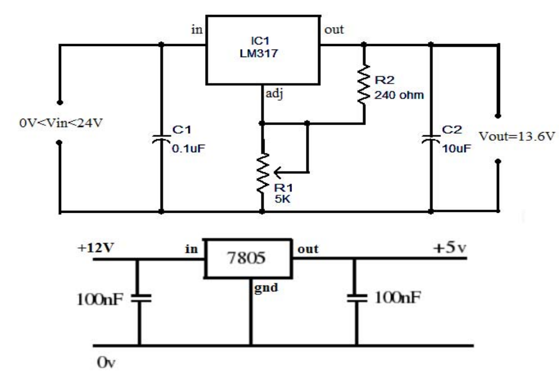

Fig. 4. Regulation circuits

frame). In the other steps, voltages coming from LDR pairs (LDR1 and LDR2, LDR3 and LDR4) are compared. If the absolute difference between the voltages coming from LDR pairs are bigger than a preset value V_D ($|V_{LDR1}\text{-}V_{LDR2}|>V_D$, $|V_{LDR3}\text{-}V_{LDR4}|>V_D$) , the necessary logic signals produced and sent to L298 IC DC motor drive. At the end, motor 1 and motor 2 are turned in such directions that the absolute values of voltage differences becomes less than the preset value and the motors are stopped. Theoretically, the above voltage differences become zero when the solar rays are normal to the PV panel. But, when the value of V_D is taken as zero in the code in practice, the frame of the PV panel keeps shaking and the controller cannot find a stable position of PV panel. This is due to error in the placement of the LDRs on the PV panel frame and mechanical stability problem of gear mechanisms of DC motors. Due to the above reasons, V_D value is taken as approximately 0.2 volt in the code.

2.5. Mechanical Structure

The complete mechanical structure of the proposed two axis solar tracker is illustrated in Fig. 5. All of the mechanical structure has been designed and implemented in Eskisehir Osmangazi University laboratories. Aluminum has been used in body of the tracker since it is light and pretty strong metal to hold up the weight of PV panel. Pole of tracker has been made up of metal groove and fixed to chopping block at the bottom. LDRs have been placed on the frame of PV panel as shown in Fig. 5. Two DC motors with gears are used to obtain the required torque to move the PV panel in altitude and azimuth angle tracking. In this mechanical structure, two similar gears are used for two axis tracking system. Building a simple and cheap structure is aimed with this mechanical design.

3. Experimental Results

A PV panel with 40x90 cm is used in our design. Maximum output voltage from the PV panel is 24 volts. The output voltage from the PV panel has been measured during a sunny day at fixed 37˚ position toward south-east and with the solar tracker in

Fig. 5. Mechanical structure of two axis tracker

Eskisehir. The average output voltage from the panel is 16.32 volts when the panel is at the fixed position. However, the same average voltage is 21.48 volts when the position of the panel is controlled by the solar tracker. Fixed systems cannot utilize productive sun radiation all day long. Especially, the efficiency of the PV panel is minimal in the morning and sunset times. Reflection rate of the PV panel is also greater than that of PV panel with tracker system. Two axis solar tracker faces the PV panel to sun in the right-angled position all day long. Thus, most of the received sun rays are absorbed by the PV panel. Reflection is also reduced. Different motor types have been tried for tracker system. Stepper motor has been used but, too much power has been needed to provide the stability of tracker positions. Since using stepper motors has decreased the efficiency of system, DC motors with gear arrangements have been used instead. An advantage of using stepper motor is to have knowledge of its shaft position during the operation. Since the used DC motor does not have this property, this problem is solved by using a trimpot mounted on the shaft of DC motor 1.

4. Conclusion

This paper presents design and realization of a two axis solar tracker system. The tracking controller is implemented by means of ATmega328p microcontroller. The necessary software is developed via Arduino Uno IDE. In building the solar tracking system, LDRs (Light Dependent Resistors) are used to determine solar light intensity. The proposed solar tracking system can track sun light automatically. Reflection on the PV panel has been decreased and, the efficiency of solar energy generation is increased. DC motors with gear arrangements have been used to provide better stability for the PV panel. Using DC motors make possible minimum energy usage for the tracking system. The necessary experimental work has been carried out to show that the designed solar tracker system works as it is intended.

5.References

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