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Empirical Survey of the Solar System Based on the Fusion of GPS and Image Processing

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***Abstract*—**The tremendous increase in the population of the world creates the immediate need for the energy resources. All the people in the world need the sustainable energy resources which have low costs. Solar energy is appraised as one of the main energy resources in warm countries. The areas in the west of India like Rajasthan, Gujarat, etc. are immensely rich in solar energy resources. This paper deals with the development of dual axis solar tracker using Arduino board. Depending on the astronomical estimates of the sun from the GPS and sensor image processing outcomes, a methodology is proposed to locate the position of the sun to obtain the maximum solar energy. Based on the outcomes, the solar tracking system figures out whether to use image processing outcomes or astronomical estimates to attain the maximum efficiency of the solar panel. Finally, the experimental values obtained from the solar tracker for both the sunny and the rainy days are being tabulated.

***Keywords*—**Dual axis solar tracker, Arduino board, LDR sensors, global positioning system.

I. INTRODUCTION

SOLAR energy is quickly gaining additional importance in increasing the renewable energy resources. This energy has the large risk of conversion into power. This paper is initiated to vanquish the loss in power generation on the solar battery. This may be done by succeeding the high intensity of the sunshine created by the sun rays. Solar battery is machine-controlled to follow the purpose of high intensity of the daylight victimization LDR (light dependent resistor) sensors. This sensing element helps to sense the extreme temperature created by the sunlight on the panel surface and it is sent to the microcontroller. This device sends the feedback to the servo motor that permits the servo motor to rotate the panel to receive the high intensity of the daylight. For this, we have to locate the exact position of the sun. This can be done using the Astronomical estimates from GPS. Furthermore, the tracker is kept under experiment for obtaining the readings on both the sunny and rainy days and the results are tabulated. By this strategy, it is doable to conserve the full quantity of power created by the panel by receiving the highest intensity sunlight. Fig. 1 shows the various types of solar trackers.

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Fig. 1 Various Types of Solar Trackers

II. EXISTING WORK

The existing work does not include the experimental survey of the tracker for different weather conditions. On one hand, we can see the depletion of the energy resources to be a major problem. On the other hand, global warming is increasing rapidly, which is a major concern. In order to search for other power generation process, the best and easiest way of power generation is done by using the solar tracker. In the existing system, all the solar panels are working in static movements [1]. They are not able to locate the position of the sun and they cannot distinguish between the presence and absence of sunlight. This method of implementation doesn't produce a constant output from the solar panel which leads to a loss in power generation obtained from the panel [2].

III. CONCEPTUAL MODEL OF THE SOLAR TRACKER

To incur the loss from the static panels, we have to build an active solar system which works according to the weather conditions and the movement of the sun. The system should not be passive and novel system [3], [9]. Since the solar panel generates the power, according to the intensity produced by the source of light, we have to design the system to track the high intensity by itself. This is done by implementing the system with sensors which senses the amount of intensity produced by the light source. The proposed system is capable of rotating to 360 degrees (North – South 180 degrees & East – West 180 degrees). The rotation is achieved using the pair of servo motors and the LDR sensors [4].

In previous tracking methods, the sun has been tracked from east to west (0-180 Degrees) only. Even though sun rises in east and sets in west, it has slight variation in angles on north and south direction throughout the year. The angle variation in north and south direction changes every month. This variation is not tracked in existing systems. This leads to a loss in power generated by the solar panel.

IV. Working Methodology

A. Solar Tracker

Solar tracker may be a device that follows the movement of the sun because it rotates from the east to the west on a daily routine [5]. The solar systems need to supply one or 2 degrees of freedom in movement. Trackers keeps the solar panels orienting directly towards the sun because it moves through the sky each day. These solar trackers will increase the intensity of the solar power that is received by the solar power collector and improves the energy output of the heat/electricity that is generated. Solar trackers will increase the output of solar arrays by 20-30% that improves the political economy of the solar panel applications [6]. The two basic types of solar trackers are single-axis and double-axis. In this proposed system, we are using Dual axis tracking system. Dual axis tracker as shown in Fig. 2 has two degrees of freedom that act as axes of rotation.

Fig. 2 Dual Axis Solar Tracker

B. Working of the Solar Tracker

The conceptual model of the solar system consists of LDR sensors which provide feedback to the Arduino Board. This Arduino board processes the sensor input and provides two PWM signals for the movement of servo motors. This servo motor moves the solar panel towards the higher density of solar light. The entire solar system is powered by a 12volt source power supply. Initially five different analog values are obtained from LDR's, and then they are fed to the Arduino board. The Arduino board gives two different PWM signal for the movement of solar panel through servo motor. The current time, as well as the latitude and longitude positions of the solar tracking system, can be acquired by GPS. Using that information, the current azimuth and altitude angles of the sun can be estimated by an astronomical formula [7], [8]. However, the current heading angle of the solar tracking system may not be correct, and it cannot be updated from the GPS measurement. Therefore, in our study the camera sensor is used to more accurately determine the position of the sun. The optical media and the interfaces are used for obtaining better heat equilibrium on the solar panel [11]. The position of the sun is computed by image processing and the results obtained displays the power generated by the panel on different weather conditions.

V. Solar Tracking Methods

A. Astronomical Tracking Method

The azimuth and altitude angles of the sun are calculated by the celestial formulas. The position of the earth is updated every minute to minimize unnecessary power consumption [10]. The algorithm needs the input such as latitude, longitude, and time, which can be acquired from the solar tracker, GPS for calculating the position of the sun.

The number of the Julian days is defined as d and is obtained using (1), [3] and [4].

$$d = 367 \times Y - (7 \times (Y + ((M + 9)/4) + (275 \times M)/9 + D - 730530 \quad (1)$$

In (1), Y, M, and d represent the year, month, and day, respectively, which are obtained by GPS. Eccentricity (e), angle from ascending node to perihelion (w), mean anomaly (M), mean longitude (L), eccentric anomaly (E), and declination (a) are defined by (2)-(7):

$$\mathrm{e} = 0.016709 - (1.151 \times 10^{-9} \times d) \quad (2)$$

$$w = 282.9404 + (4.070935 \times 10^{-5} \times d) \quad (3)$$

$$M = 356.0470 + (0.9856002585 \times d) \quad (4)$$

$$L = M + w \quad (5)$$

$$E = M + [(180/\pi) \times e \times \sin(M) \times (1 + e \times \cos(M))] \quad (6)$$

$$\propto = 23.4393 - (3.563 \times 10^{-7} \times d) \quad (7)$$

The x and y rectangular coordinates for elliptic Coordinates are obtained using (8) and (9). True anomaly (v) is obtained using (10). Celestial longitude (l) and distance (r) for calculating celestial longitude are obtained using (11) and (12).

$$x = \cos(E) - e \quad (8)$$

$$y = \sin(E) \times 1 - e^2 \quad (9)$$

$$v = \tan^{-1}\left(\frac{y}{x}\right) \quad (10)$$

$$r = x^2 + y^2 \quad (11)$$

$$l = v + w \quad (12)$$

The perpendicular ecliptic coordinates are transformed to an equator coordinate system using (13).

$$\left.\begin{aligned} x_{equat} &= r \times \cos(l) \\ y_{equat} &= (r \times \cos(l)) \times \cos(\propto) \\ z_{equat} &= (r \times \cos(l)) \times \sin(\propto) \end{aligned}\right\} \quad (13)$$

The right ascension (RA) and declination (De) of the sun is obtained using (14) and (15):

$$RA = \tan^{-1}\left[\frac{y_{equat}}{x_{equat}}\right] \quad (14)$$

$$De = \tan^{-1}\left(\frac{z_{equat}}{\sqrt{x_{equat}^2 + y_{equat}^2}}\right) \quad (15)$$

Greenwich Mean Sidereal Time (GMST) and sidereal time (SIDTIME) are defined by (16) and (17). The hour angle (ha) is obtained using (18).

$$GMST = \frac{L}{15+12} \quad (16)$$

$$SIDTIME = GMST + UT + LON/15 \quad (17)$$

$$ha = SIDTIME - RA \quad (18)$$

The z-axis transformation in the direction of the zenith is defined by (19)-(21). In (19)-(21), lat represents the latitude of the tracker.

$$X_{hor} = (\cos(ha) \times \cos(De) \times \sin(lat)) - \sin(De) \times \cos(lat)) \quad (19)$$

$$Y_{hor} = \sin(ha) \times \cos(De) \quad (20)$$

$$Z_{hor} = (\cos(ha) \times \cos(De) \times \cos(lat)) - \sin(De) \times \sin(lat)) \quad (21)$$

Finally, the azimuth and altitude of the sun [12] are obtained using (22) and (23):

$$Azimuth = \tan^{-1}\left(\frac{Y_{hor}}{X_{hor}}\right) - 180 \quad (22)$$

$$Altitude = \sin^{-1}(Z_{hor}) \quad (23)$$

B. Solar Image Tracking

The conventional solar image tracking method using an optical sensor seems to be less efficient because it often mistakes the sun for its light scattered by clouds or other obstacles in the way. Therefore, it is important to find the widest range for the location of the sun through pixels which are separated by its color.

Although astronomical estimates from the celestial formula are expected to provide an accurate position of the sun, the actual solar panel could be facing away from the normal direction of the sun because of the tracking system movement.

VI. Experimental Results

Using the tracking method that fuses astronomical estimates and the solar image, the solar tracker panel can maintain its position facing the normal direction of sunlight. However, when the weather is cloudy, controlling the tracker by solar image is not desirable because it is difficult to locate the sun using the solar image. In such a case, it is better to employ only astronomical estimates instead of their fusion with image processing.

Fig. 3 Examples of sun positions during regular Time intervals in sunny and cloudy days

The power output for the sunny and the cloudy days are tabulated for a single day. The average power values prove that the sunny day output produces more power than that of the cloudy day output power values. The power efficiency calculated from the sunny day by the tracker is said to be 25% more than that of the cloudy day readings. The readings are tabulated in Table I.

TABLE I
Power Output Values from the Solar Panel for Two Different Weather Conditions

HOUR	CLOUDY DAY	SUNNY DAY
7:00	15.575	37.8
8:00	24.88	50.28
9:00	41.876	53.21
10:00	46.94	55.61
11:00	52.01	54.74
12:00	56.66	59.616
1:00	56.96	58.488
2:00	55.5	57.87
3:00	53.68	55.31
4:00	47.174	53.82
5:00	35.96	52.98
6:00	26.83	51.78

The graph which is obtained for the power output values of the table is shown in Fig. 4.

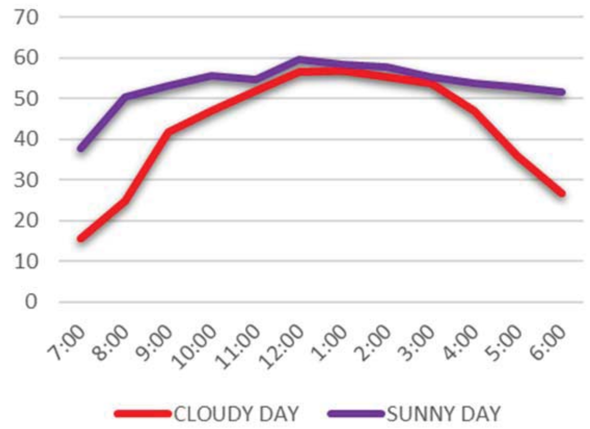

Fig. 4 Power output values obtained by the tracker

VII. Conclusion

In this paper, we have presented a solar tracking system and an algorithm that uses astronomical estimates of solar position and solar image processing results. This technology of tracking is very easy and simple in design, reduced in cost and precise in tracking. A variety of technologies for the solar energy are available on the market. But this tracking technology, which is based on dual axis has higher energy gain comparing with both fixed solar panel and single axis solar tracking technologies and it is also very efficient. We expect that the proposed method will improve acceleration of the solar cell module due to the high precision in determining the position of the sun and robustness of the system in all weather conditions.

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