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Comparative Study of Various Solar Photo Voltaic Tracking Systems

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Abstract : Solar energy is the most abundant form of energy present to us. Our aim is to put forward methods for its maximum utilization. Various methodologies have been devised for the extraction of solar energy. This paper provides a comparative study of various tracking methods for optimization of solar power. This energy is obtained using solar photovoltaic panels. It is setup consisting of solar panel, driver circuit for harnessing the solar energy and Arduino (ATmega16) for running the various optimization algorithms. Space-time synchronization method, equal time method and LDR method have been compared.

Keywords : Photovoltaics; single-axis tracker; space-time synchronisation method; equal time method; azimuthangle; zeneith angle; LDR method; arduino; DC motor.

1. INTRODUCTION

The increasing demand for sources of energy with their equally fast depletion draws our attention towards the non-conventional sources of energy. Solar energy is the most abundant form of energy available on earth. The intensity of solar energy is controlled by the diurnal and seasonal movement of earth [1]. The solar irradiance reaching the surface of the planet is twice as much as the resources including coal, oil and natural gas. Ironically, highest tapped efficiency of solar photovoltaic cells is about 25%, with average being only 15-20%. Hence, it is important that we improve upon the solar energy yield by hook or by crook. Solar energy yield can be increased by employing a single-axis and dual-axis solar tracker. Solar tracking is one of the various techniques used to increase the efficiency of solar panels [2]-[4].There aretwotypes of panel usage:

1. In fixed form and
2. In solar trackers

When a panel is fixed they are tilted in ground oron a roof at an angle appropriate for sun's radiation. In solar trackers the panel is made to rotate in the directionswith respect to sun. Light gathering by solar panels is dependent on the angle of incidence of light rays to the solar cell's surface [5]-[7].One simple method devised by Weston Sapia & Jason Birnie is to use MOSFETS and diodes to track the sun's rays this avoids the bulkiness of the PV arrays but since the equipment is dealing with sensitive electronic devices the longevity of the devices is a big question [8]. Other research work drags our attention towards the microcontroller/microprocessor approach. A very smooth and easy control can be obtained from it. The microcontroller/microprocessor can be programmed to the panel in the direction of sun's rays in order to obtain maximum intensity. Various programs can be applied for the movement of single-axis and dual-axis solar panel with more precision [9]-[21].Arduino(ATmega16 microcontroller) being more user friendly, portable, compact and advanced can be considered as suggested by many researchers[22]-[23]. For better results methods such as LDR sensor method, Equal time method and Space-time synchronization method have been introduced. These methods increase the efficiency of solar tracking [23]-[30].In this paper all the three methods are employed and comparative study has been made.

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A system has been developed to perform various tracking methods. The solar panel is controlled using a motor which also uses a gear to reduce its speed. Two LDR sensors are placed at corners of the panel. These sensors calculate the solar irradiance which is then compared. The program is carried using a microcontroller. Motor driver circuit is present which increases the voltage from microcontroller level to motor level.

Uniform tracking method uses various parameters to determine the length of the day. This is then used to rotate panel over the day. LDR method uses comparison of two solar intensities to get a position of solar panel. Various algorithms to calculate this position are available. This can be used to position the panel correctly.

2. OBJECTIVES

The objective of this paper is to compare various solar tracking methods which are:

- LDR method, Equal-time method and Space Time Synchronization method.
- Single-axis and Dual-axis tracking Systems

3. METHODS OF SOLAR TRACKING

Solar tracking is one of the most appropriate technologies so as to increase the efficiency of the solar panels. Rather than purchasing additional panels, they help to harness solar energy in more efficient way even with respect to cost. There are two major types of trackers: Passive Tracker and Active Trackers. Two types of active trackers are used in this comparative study:

A. Single Axis Tracking System

Single axis tracking system realizes the movement along the elevation or azimuth angle of the sun. A single axis tracker can pivot in only one plane: Horizontal or Vertical. For this kind of tracker only one motor is required. This tracker is comparatively less complicated and generally cheaper. Single axis tracker analyzed in this paper is a PV panel fixed onto a mechanical frame under the action of a bidirectional DC motor which controlled by an Arduino.

B. Dual Axis Tracking System

A dual axis tracker can pivot in both the horizontal and vertical plane. These trackers realize movement both along azimuth and elevation angle. This tracking system overcomes the disadvantages of the single axis tracking system. Dual axis tracker analyzed in this paper is controlled by two DC motors. One direction of rotation is based on the output of the LDRs and the other is controlled by a program fed in the Arduino called the uniform tracking method.

4. TRACKING METHODS

A. LDR Based Tracking Method

This method uses two LDRs to detect the intensity of sunlight and accordingly decides the motion of the panel. The output of these two LDRs is fed to the Arduino Uno where the output of each LDR is sampled and then compared. The error signal goes to the micro controller which activates the respective relay which controls the direction of the motor. Hence,the panel rotates and makes real time adjustment of the incident angle between the sun's rays and solar panel.

B. Uniform Tracking Method

As for this method the earth rotates at a constant speed, 24hr for one rotation .If 180°rotation is considered for 12hrs then for every one hour the sun rotates by 15°. This is implemented by a program that will rotate the panel 15° every one hour. This program is feed to the Arduino UNO.

The Arduino hence activates the relay that controls the motor rotation.

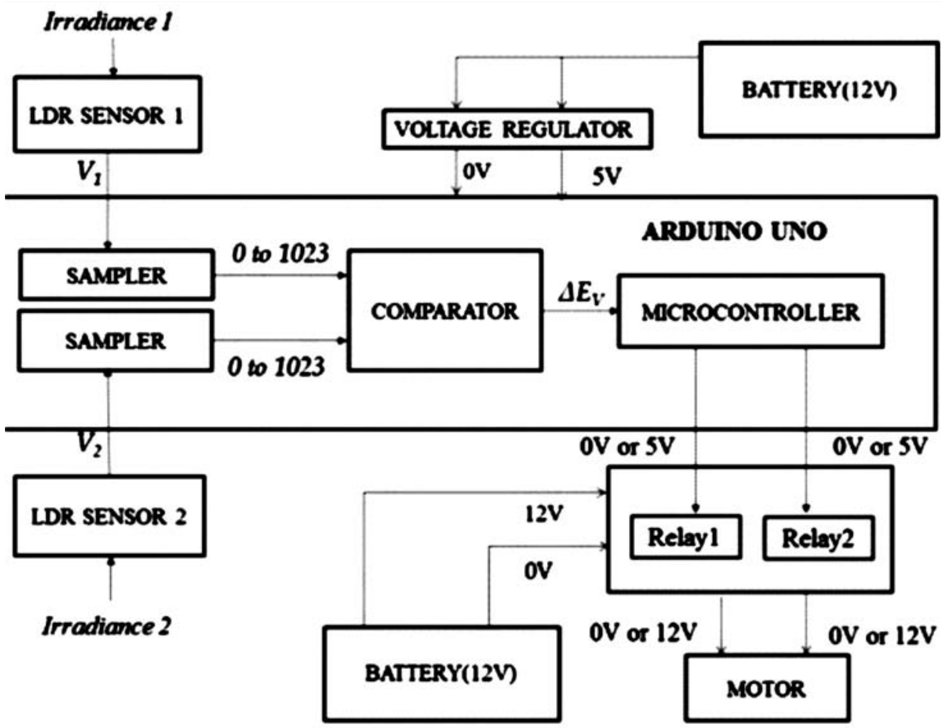

Figure 1: Block Diagram for LDR Based Method

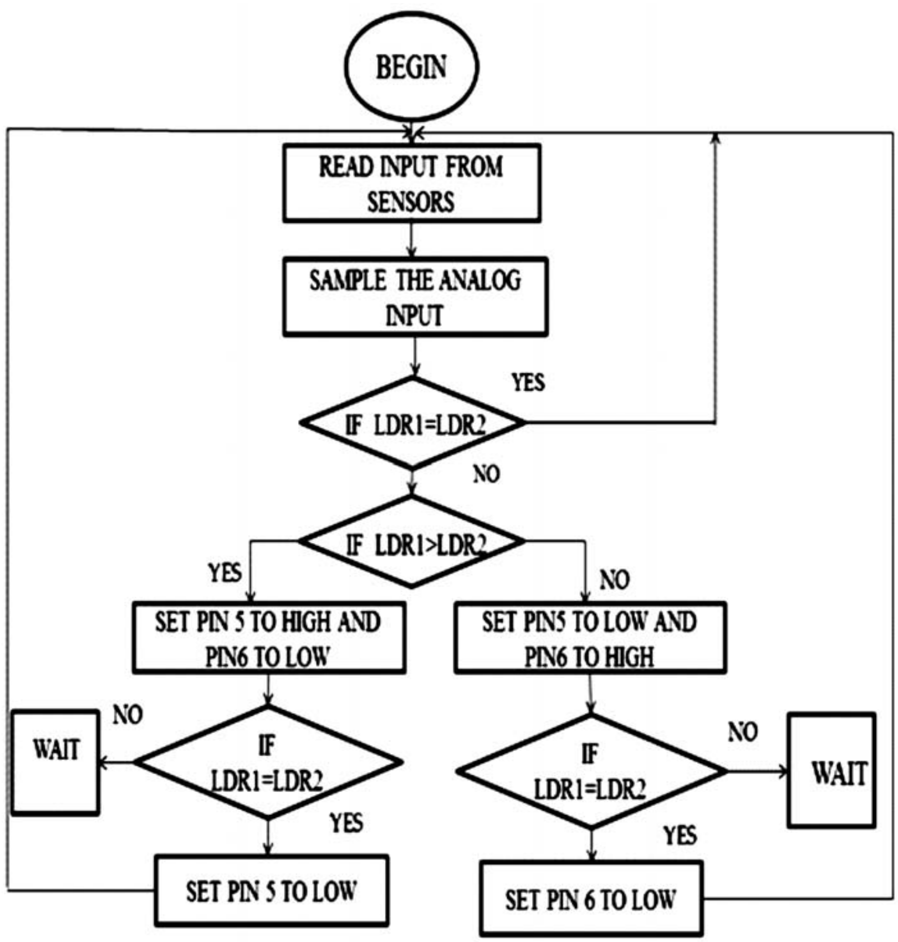

Figure 2: Flow Chart of LDR Tracking Method

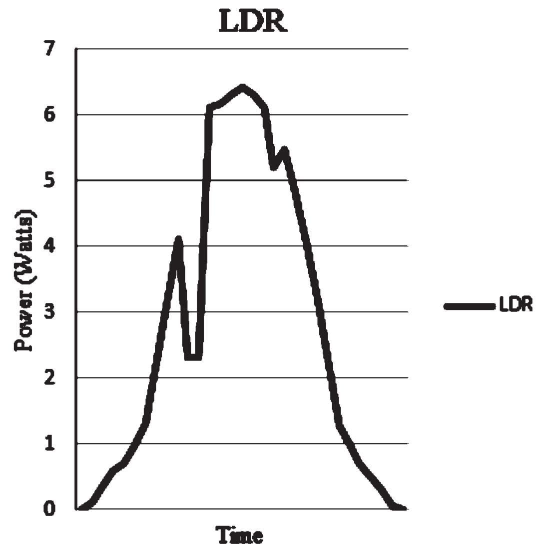

Figure 3: Graph for LDR Tracking Method

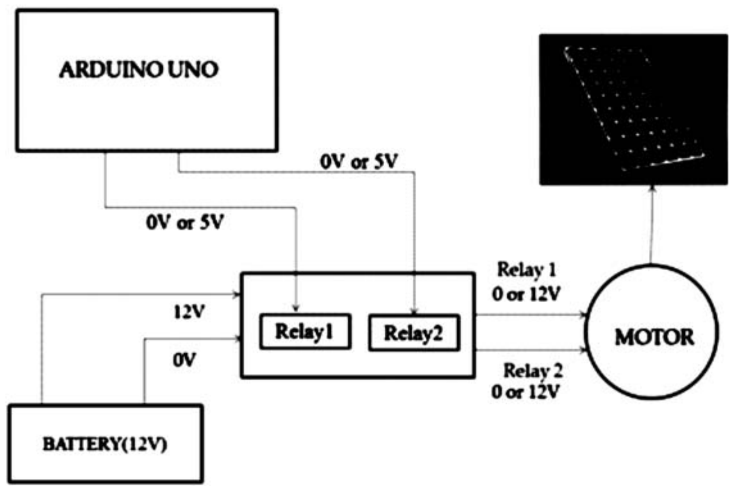

Figure 4: Block Diagram for Uniform Tracking Method

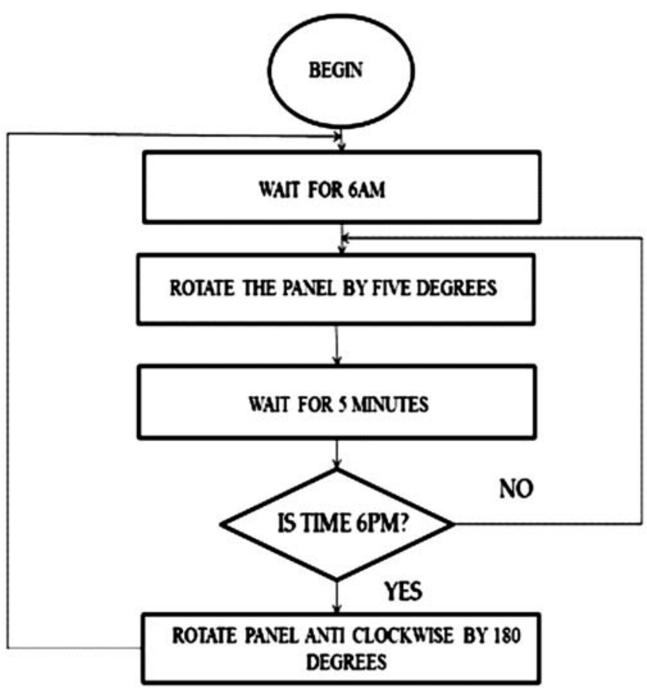

Figure 5: Flow Chart for Uniform Tracking Method

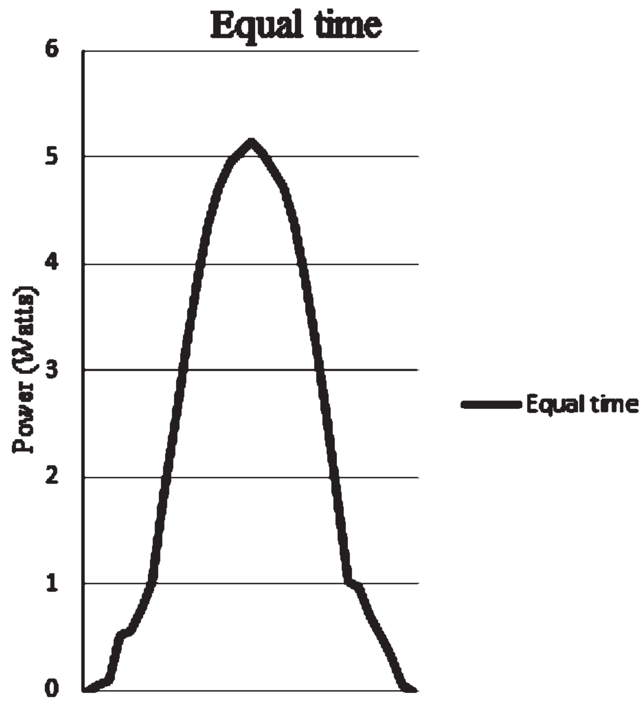

Figure 6: Graph for Uniform Tracking Method

C. Space Time Synchronisation Method

This method is based on the same block diagram as that of uniform time tracking. The difference between both the methods lies in the program that is fed to the Arduino. In this process an algorithm is used called the Solar Position Algorithm. This algorithm calculates the solar zenith and azimuth angles in the period from the year -2000 to 6000, with uncertainties of +/- 0.0003 degrees based on the date, time, and location on Earth. This way the solar panel rotates to follow the position of the sun very accurately.

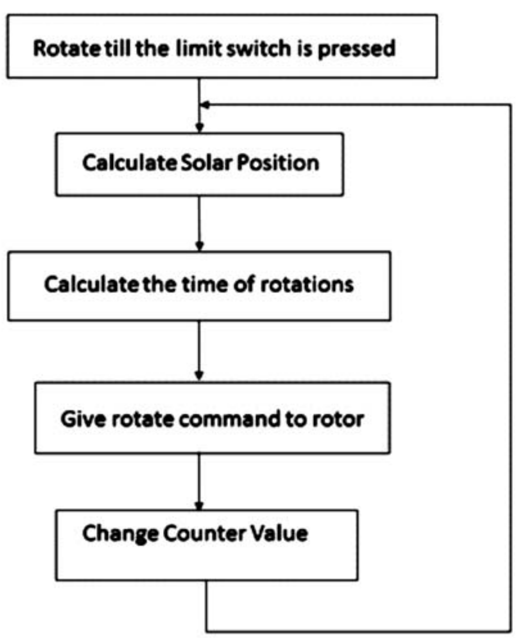

Figure 7: Flow Chart for Space Time Synchronization method.

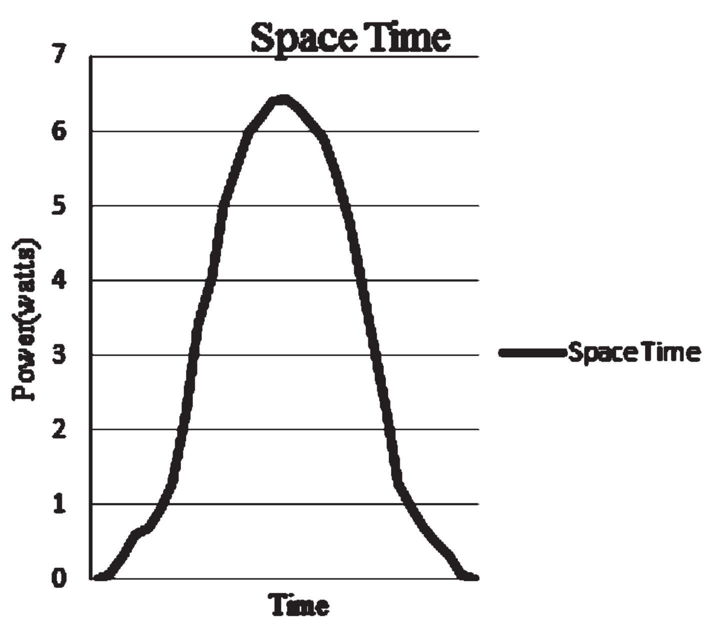

Figure 8: Graph for Space Time Synchronization Method

5. OPERATION

The motion of the dual axis solar tracker is controlled by two 12V DC motors which are controlled by relay action(relay A and relay B).The motion of the panel in horizontal direction is controlled by screw type gear and in vertical direction it is controlled by spur gear .The relay A action is controlled by LDR sensor method.The two LDRs are kept on both the ends of the panel. As the sunrays falls on the panel, both the LDRs senses the irradiance falling on them and the output of the LDR sensors goes to the Arduino where they are sampled and compared. The LDR on which higher intensity of light falls, the Arduino generates an output signal which will activate relay A and rotate the panel in the direction of higher intensity of sunlight.Relay B action is governed by uniform tracking method .In this method the Arduino runs a program where in the panel rotates 15° for every hour.

A 12V DC battery is used to operate the two DC motors. This 12volts using voltage regulator7805 is reduced to 5V which is used to power the electronic circuits and Arduino.

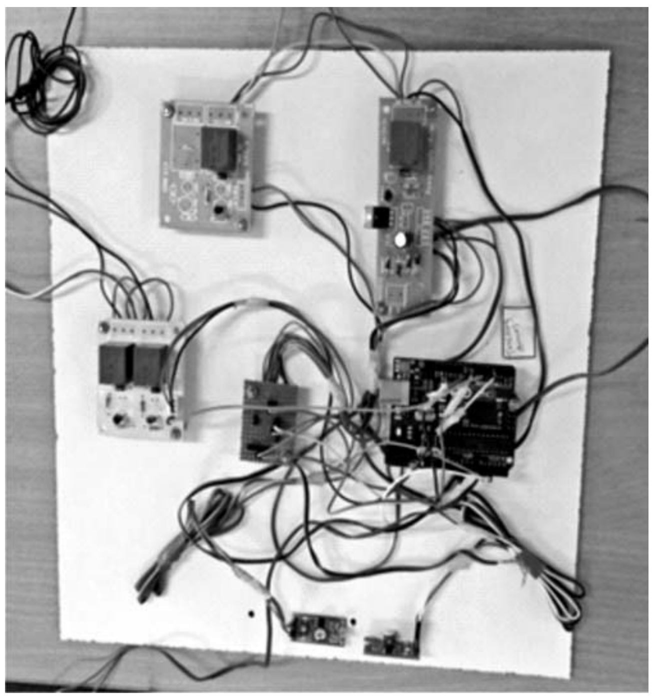

Figure 9: Electronic Setup

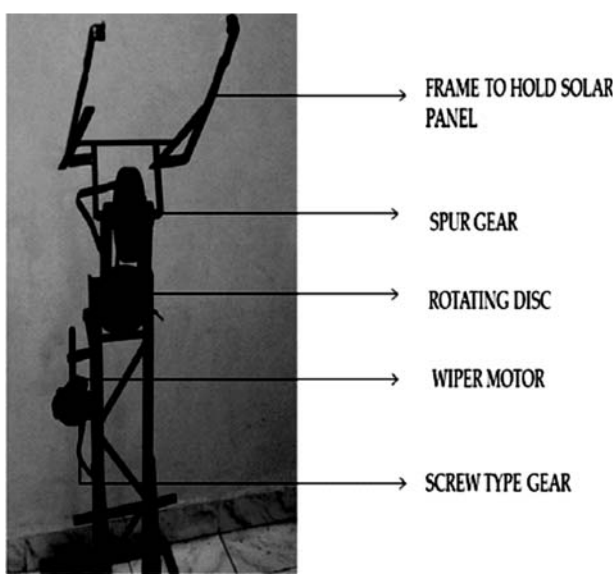

Figure 10: Electronic Setup

6. RESULT

Single-axis solar tracker has only one degree of rotation so it does not accurately point towards sun. This results in slight decrease in power as compared to dual-axis tracker, as dual axis tracker accurately points towards the sun. In countries like India which are close to equator the difference is subtle. But in countries away from equator the effect may be pronounced.

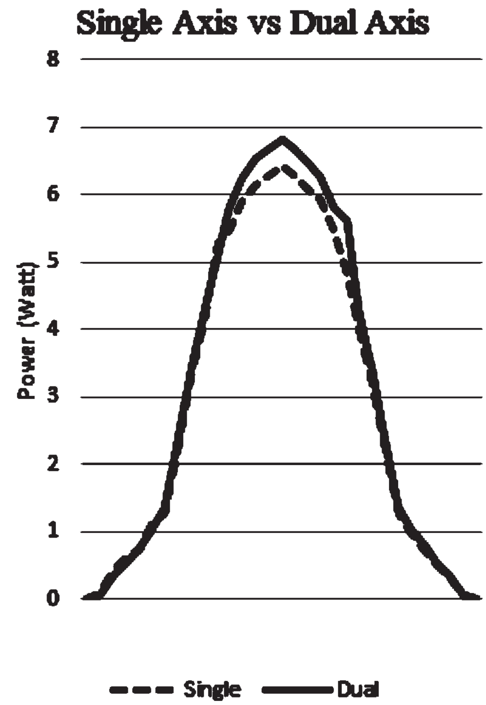

Figure 11: Comparative Graph for Single Axis and Dual Axis

Equal time method that is used shows a flat curve. This is because it might not directly point at sun. The power is kind of average in this case. LDR values are almost close to the single-axis values but power drops a couple of times. This was because of the clouds that were present. Also the panel kept rotating abruptly. So this particular case is not suitable for the cloudy weather. Space time method is very accurate but the algorithm is very complex.

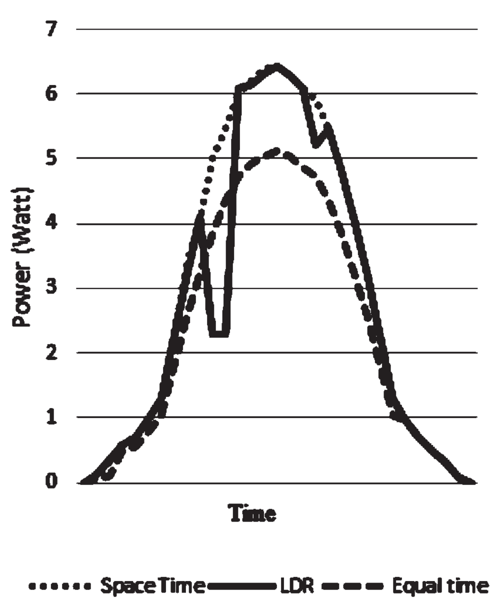

Figure 12: Comparative Graph for Various Methods

7. CONCLUSION

The tracking methods are very useful for continuous use. The three methods have advantages and disadvantages. The uniform tracking method issimple andinaccurate. The LDR based method is simple, and has high accuracy, but could not work in the overcast environment. And space time synchronization method is precise, but the program is complicated. Depending on various situations and practicability various tracking methods can be implemented. The space time synchronization method is the most accurate of all the methods. Many other methods can be used for further optimization of power.

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