Fabrication and Development Low Cost Dual Axis Solar Tracking System

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Abstract. Solar energy is gaining importance day by day as an energy resource. By sun tracking we can increase the electric energy of solar panel. When the solar panel is perpendicular to the sun's rays it receives more sunlight. This paper about follow the sunlight direction across the sky by using a DC motor(satellite motor), the LM324 IC control the movement of DC motor by this the solar panel will change their position, solar panel detects the sunlight using four light dependent resistors (LDRs). The objective is to design and implement an automatic solar-tracking mechanism using an embedded system design with minimum cost and reliable structure. The results presented in this review confirm that the azimuth and altitude dual axis tracking system is more efficient compared to other tracking systems.

Keywords: LM324 IC, solar-tracking, solar panel, solar energy, Dc motor.

1. Introduction

The increasing demand of energy, the depletion of fossil fuel reserves, the unexpected events taking place on the international scene (local armed conflicts, natural disasters like earthquakes, tsunamis, floods, hurricanes, etc. That have the potential to partially cripple the energetic systems, proves that the energy security and diversity is a serious aspect that mankind should seriously consider when deciding the short and middle term energy policy. The general opinion shared by the most part of the specialists supports the idea that the exclusive dependence on the energy produced from fossil fuels (coal, oil, nuclear, etc.) is hazardous, unsustainable and harmful for the environment. In this context, many developed countries (e.g. USA, Germany, Spain, Denmark, France, Italy, etc.) launched in the last Decade’s ambitious programs for supporting the rapid development of alternative energetic technologies based on solar energy, wind energy, tidal and wave energy, biomass etc. One of the most promising renewable energy sources characterized by a huge potential of conversion into electrical power is solar energy. The conversion of solar radiation into electrical energy by Photo-Voltaic (PV) effect is a very promising technology, being clean, silent and reliable, with very small maintenance costs and small ecological impact. The interest in the PV conversion systems is visibly reflected by the exponential increase of sales in this market segment with a strong growth projection for the next decades. According to recent market research reports carried out by European Photo Voltaic Industry Association (EPIA), the total installed power of PV conversion equipment increased from about 1 GW in 2001 up to nearly 23 GW in 2009 [1].
Different researches estimate that covering 0.16% of the land on earth with 10% efficient solar conversion systems would provide 20 TW of power, nearly twice the world’s consumption rate of fossil energy [2]. This proves the potential of solar energy which in turn points out the necessity of tracking mechanism in solar systems. The tracking mechanism is an electromechanical system that ensures solar radiation is always perpendicular to the surface of the photovoltaic cells (solar cells) which maximizes energy harnessing [3]. Over the years, researchers have developed smart solar trackers for maximizing the amount of energy generation. Before the introduction of solar tracking methods, static solar panels were positioned with areas on cable tilted angle based on the latitude of the location. In this competitive world of advanced scientific discoveries, the introductions of automated systems improve existing power generation by 50% [4]. There are mainly two types of solar trackers on the basis of their movement degrees of freedoms. These are single axis solar tracker and dual axis solar tracker. Again these two systems are further classified on the basis of their tracking technologies. Active, passive, and chronological trackers are three of them [5, 6]. Previous researchers used single axis tracking system which follows only the sun’s daily motion [7]. But the earth follows a complex motion that consists of the daily motion and the annual motion. The daily motion causes the sun to appear in the east to west direction over the earth whereas the annual motion causes the sun to tilt a particular angle while moving along east to west direction [8].

2. Solar Tracker

One of the factors that can improve the efficiency of the photovoltaic system is the availability of solar tracking mechanism in the system [9]. There are typically two types of solar tracker designs available i.e. one and dual axis solar tracker. The one axis solar tracker consists of a horizontal-axis tracker which always oriented along East-West or North-South direction; tilted-axis tracker which is tilted from the horizon by an angle oriented along North-South direction; and vertical-axis tracker also known as an azimuth sun tracker as shown in figure 1. The dual axis solar tracker consist of azimuth-elevation and tilt-roll sun tracking systems, follow the sun in the horizontal and vertical plane as shown in figure 2. A solar tracker is a device that orients a solar panel toward the sun. The solar tracker techniques can be used as a sun tracking algorithm or light tracing sensors [10].

![Figure 1. The single solar tracker: (a) Vertical – single axis tracker (b) horizontal-single axis tracker.](image-url)
3. Experimental part.

Mechanical Tracking Design

The first part fabricated is the frame of the structure as following

1. Metal pipes are cut using a special metal saw to the required lengths:
   
   (60 cm * 2, 100 cm * 3, 90 cm * 1, 15 cm * 1).

2. Metal pipes shall be welded to form the solar cell-bearing base.
3. The metal base above is welded to the fixed metal stand or rack.
4. Connect the motors between the base and the metal stand, as well as in Figure 3:

   ![Figure 3. Mechanical tracking design.](image)

   **Figure 3.** Mechanical tracking design.

**DC Motors**

The motors used to rotate the axes are satellite motors, figure 4. They are pretty known for their long service life and their wind and rain with standing potential. The tight seal will prevent water from penetrating to the inside. The rugged aluminum casting maintains the greatest strength in high stress areas. Their large bearing surfaces and strongly reinforced mast support lateral loads. Ball bearing is provided to hold the thrust (vertical) loads. The more important features of these motors are their high torque capabilities and precision in positioning. Almost all houses in cities, where satellite broadcasting is available, have one setup using this type of motors. So usually it is cheap and abundant in the market and people can easily maintain it.

   ![Figure 4. Satellite motor.](image)

   **Figure 4.** Satellite motor.
3.3. Electronic circuit

There are many electronic circuits for solar pursuits, simple and complex ones, some of which are made up of known electronic components such as the timer 555 [11]. The Arduino or Microcontroller, which can be programmed and erased several times, has developed and manufactured a simple electronic circuit and simple and inexpensive components where anyone can manufacture it. An electronic circuit for the single axis tracker and another electronic circuit that is similar to the Horizontal-single axis tracker as shown in Figure 5.

![Diagram of the electronic circuit.](image)

**Figure 5.** Diagram of the electronic circuit.

**Light sensors (R_{LDR}).**

The tracker tracks the sunlight by four light-based resistors (LDR) at the top of the solar cell panel looking for sunlight and identifying it on either side (east, west, north or south) and then moving to find the best point of sunlight as shown in figure 6. A light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. Figure 7. shows the Basic diagram of LDR circuit [12].

![Four R_{LDR} kits.](image)

**Figure 6.** Four R_{LDR} kits.
Figure 7. Basic diagram of LDR circuit.

IC. LM324

LM324 as denoted in figure 8, is a 14 pin IC consisting of four independent operational amplifiers (op-amps) compensated in a single package. Op-amps are high gain electronic voltage amplifier with differential input and, usually, a single-ended output. The output voltage is many times higher than the voltage difference between the input terminals of an op-amp. These op-amps were operated by a single power supply LM324 and need for a dual supply is eliminated. They can be used as amplifiers, comparators, oscillators, rectifiers, etc. The conventional op-amp applications can be more easily implemented with LM324 [13].

Figure 8. The basic LM324 circuit.

4. Test angles axles.

The angle of rotation of the horizontal axis (330 °) of solar panel, it is moving from the extreme right to the far left to trace the motion of the sun from east to west. The angle of the vertical axis is (from 0 to 90 degrees) with any horizon moving from a level parallel to the horizon to a vertical level with the horizon to track the movement of the sun from north to south as shown in figure 9.

Figure 9. Solar cell movement to the extreme right, the extreme north and solar cell movement with the horizon line.
5. **Experimental and method.**

*Experimental Setup.*

1. **Solar Panel:** A solar cell or photovoltaic cell is a device that converts solar energy into electricity by the photovoltaic effect. The collection of solar cells is called a solar panel or solar array, which has 18 volts. Solar panel is placed on top of the tracker board which absorbs the maximum sunlight which is used as supply to the motors or stored in the battery for future use.

2. **Checking the battery (voltage display).**
3. **Connect the wires to the DC motor and power source.**
4. **Reference to optical resistance (LDR)**
5. **Rotating Variables Resistors (Trimming Tool)**
6. **Connect the power cord and turn DC motor.**
7. **Control the variable resistance (trim pot, 500 K) clockwise. Note the position.**
8. **Continue to rotate (trim pot) clockwise until the DC motor works in the opposite direction. Note the position.**
9. **Split the angle between positions in step 6 and step 7 and set the trim pot at that point. (This trim pot determines the equilibrium point)**
10. **Rotate (trim pot 47K) clockwise until the DC motor begins to search.**
11. **Pull back in a clockwise direction until the engine takes a break. (This trim pot determines sensitivity).**
12. **Check the correct operation by shading each LDR individually and in turn checking the rotation DC motor and vice versa for the other direction.**

*Results of solar panel at month of September.*

Solar panel is placed with an angle of 45 degrees with the horizon on top of the fixed system. solar panel is directed towards the base using the electronic compass. Solar panel with the stationary base is moved to an open place, for example, on a building surface, and begins by measuring the voltages of the solar panel by using an avow meter every hour from sunrise to sunset. The voltages are repeated twice per hour at the first time and the cell is stationary without the second time when the circle of the solar tracker is directed to direct the solar cell directly towards the sun so that the sun is vertical on the solar panel. Table 1. shows the fixed and the tracking systems voltage values per each hour from 6am to 6pm for one solar panel (for September).
Table 1. Electrical properties of fixed and tracking systems data (for the month of September).

| Time (hr) | Fixed-axis Voltage (V) | Dual-axis Voltage (V) |
|-----------|------------------------|----------------------|
| 6         | 17                     | 18                   |
| 7         | 18                     | 18.6                 |
| 8         | 18.32                  | 18.6                 |
| 9         | 18.33                  | 18.6                 |
| 10        | 18.6                   | 18.6                 |
| 11        | 18                     | 18.6                 |
| 12        | 17.94                  | 18.6                 |
| 13        | 17.75                  | 18.6                 |
| 14        | 17.6                   | 18.6                 |
| 15        | 17.55                  | 18.6                 |
| 16        | 16.6                   | 18.6                 |
| 17        | 15                     | 17                   |
| 18        | 12.55                  | 14.88                |

Average Voltage per Hour (V/hr.) 14.54 18.14

Figure 10. show that the relationship between time and voltage of the fixed and dual solar systems of the solar panel (for the month of September). It is quite obvious that the percentage increase in power is focused at the early and afternoon hours. After all, the fixed panel at these periods of the day will not be erected in the optimum irradiation receiving the position. Similar results are obtained for different days of the year and for different weather conditions (hot, and cold) where maximum voltage gain reached, with this type of tracking mechanism, is 5% more than a fixed one.

Figure 10. The relationship between time and voltage of the fixed and mobile solar system of the solar panel (for the month of September).
The results of solar panel at month of January.

Figure 11. and table 2. show that the measured voltage values of the solar tracker are higher than the voltage values of the fixed system for the same solar daylight hours. That means the solar tracker improved an efficiency of the solar panel compared with a fixed axis system. Where the maximum voltage gain reached, with this type of tracking mechanism, is 16% more than a fixed one.

Table 2. Electrical properties of fixed and tracking systems data (for the month of January).

| Time (hr) | Fixed-axis Voltage (V) | Dual-axis Voltage (V) |
|----------|------------------------|-----------------------|
| 6        | 16                     | 20                    |
| 7        | 16.3                   | 20.2                  |
| 8        | 16.7                   | 21.2                  |
| 9        | 19.6                   | 20.7                  |
| 10       | 20                     | 20.3                  |
| 11       | 20.2                   | 20.3                  |
| 12       | 20.5                   | 20.5                  |
| 13       | 20                     | 20                    |
| 14       | 19.9                   | 20                    |
| 15       | 19.9                   | 19.9                  |
| 16       | 19.6                   | 19.6                  |
| 17       | 18.6                   | 19.2                  |
| 18       | 15                     | 17                    |

Average Voltage per Hour (V/hr.) 17.11 19.92

Figure 11. The relationship between time and voltage of the fixed and mobile solar system of the solar panel (for the month of January).
6. Conclusions

A solar tracking system can easily increase the solar energy absorbed compared to a fixed system. However, to carry on a fair comparison with a fixed system, the inclination angle of the fixed panel must be considered and the orientation of the fixed panel should be changed once or twice a season according to the summer and winter sun arch. The power loss due to the control electronic circuit and the antenna motors is very little compared to the power gained from the tracking system. When comparing the price of PV solar panels, the cost of tracking solar energy will be relatively low. Solar Tracker reduces the space requirement of the solar power plant, and it keeps the same output. Electronic Circuit Tracker is a simple to use and inexpensive circuit.

7. References

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