Solar Powered Street Light

2 Idea

Our motive throughout the whole product developing phase was to maximise the energy harnessed by the solar panel in the limited time window available of solar radiation. For this, we propose a mechanism wherein the incidence of solar radiation will always be normal to the surface of the panel. We have tried to realize this by orienting the plane of the solar panel perpendicular to the area of maximum incident intensity via a motor at regular intervals.

3 An Overview of the Product

Our model consists of a plane base with two vertical supports lifting a motor attached to the solar panel. The motor rotates the panel along a horizontal axis, thereby orienting the panel to have normal incidence of sun rays at all time, thus maximizing efficiency of power output. There is a DC motor which rotates the solar panel about a shaft. The rotation of the panel is controlled by two LDR sensors which are placed on top of the solar panel. The voltage difference between the two LDRs is what instructs the motor to change its orientation dynamically as to face the sun at all times. The solar panel orients itself such that the LDR end with higher voltage is at a higher position relative to the one with lower voltage. This way, the panel is so oriented to face the sun at all times.

An LDR mounted on the pan recognizes nightfall when the luminescence recorded by it falls below a certain threshold value. This is done by exploiting the fact that the voltage across the LDR will be zero during the day and a certain negative saturation value during times of dim visibility. Taking the latter voltage value as reference, we aim to design a circuit which would provide voltage from the battery across the terminals of the LED when input voltage (across LDR) is zero and which would not provide any voltage to the LED when the input voltage is high (former case). Therefore, we use a NOT GATE to achieve this output characteristic.

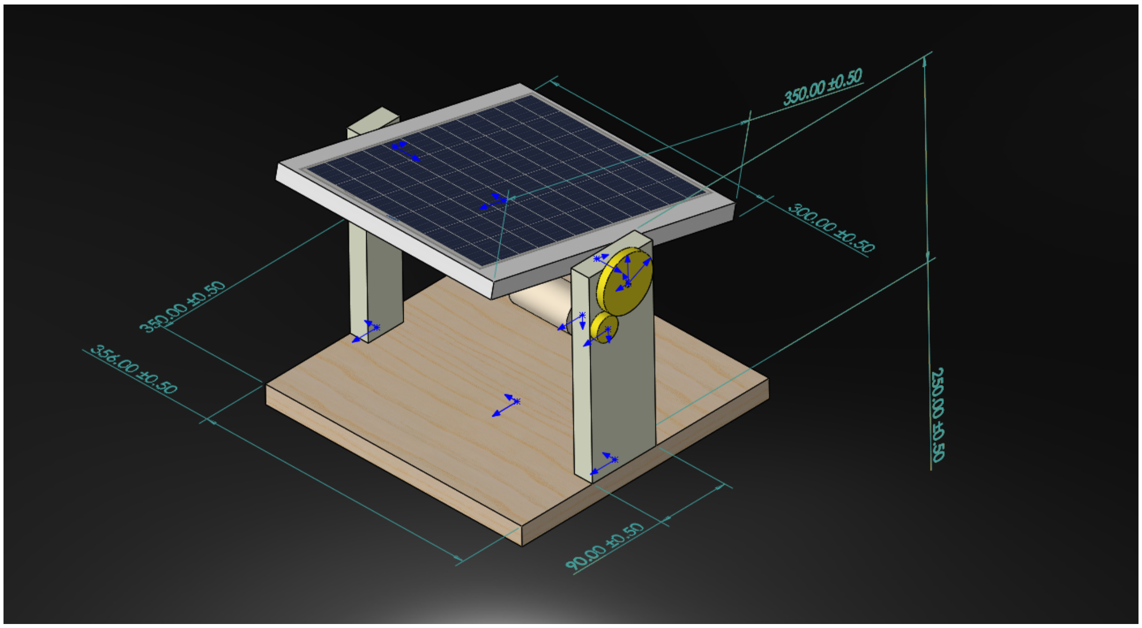
The circuit diagrams involved in the construction of our prototype are as follows:

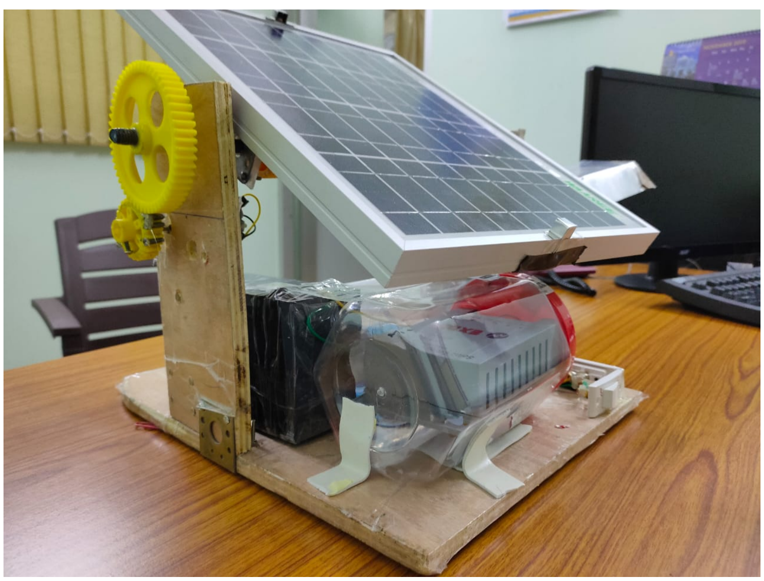
The energy stored (via harnessing) in the battery during the day is utilized at nightfall to light an LED. The parameters of the materials used are so chosen as to keep the LED lit for atleast 4 hours. Also, a solar charge controller is used to achieve the following features:
· Protect the battery from over charging.
· Reduce system maintenance.
· Increase battery lifetime.
· Indicate auto charging.
· Monitor the reverse current flow.

The entire set-up is made on a solid base. The vertical supports are attached perpendicular to the base by the means of a right-angled motor mount. Also the ends of the rod attached to the motor are drilled through the vertical support. This provides it sufficient strength to withstand high speed winds. Moreover, all the circuitry involved is enclosed in a waterproof container in order to prevent any damage due to moisture or rain. In our prototype, we have covered the base and vertical supports with a synthetic tape to make it water-proof.

In our prototype, we have made use of two gears. One for governing the movement of the solar panel, and the other for increasing friction to bring the rotation after attaining the required orientation to a stop.

The model of prototype is shown below:





3.1 Components used

- 10 W Waaree Surya Series Solar PV Module WS-10, Voltage: 600 V
- SMF VRLA Series Sealed Lead-Acid Battery 12V 7.5Ah
- OJAS5 CF32 230-42LED
- DC Motor
- Light Dependent Resistor ADTRON Model 6515
- EXIDE Solar Charge Controller

3.2 Total cost incurred

· Cost of solar panel: Rs. 900
· Cost of battery: Rs. 500
· Cost of LED: Rs. 150
· Cost of DC motor: Rs. 200
· Cost of wood for base and vertical support: Rs. 100
· Cost of LDR (3 pieces): Rs. Rs.25
· Cost of solar charge controller: Rs.370

Net cost: $\boxed{\textbf{Rs. 2245}}$

3.3 Working

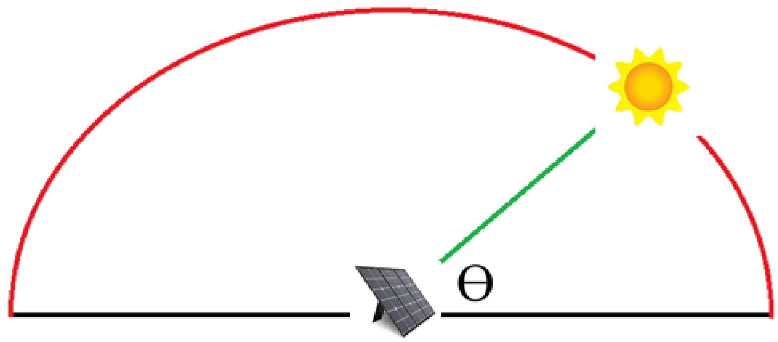
4 Some Analyses

Let us now proceed to do some important analysis regarding our prototype.

4.1 Efficiency Analysis

In this section, we aim to compare the efficiency of our model with a trivial scenario, when a fixed solar panel is used to harness solar energy.

Let the angular velocity of the sun across the sky as seen from the frame of reference of the panel be ω. Let T be the time taken for the sun to set as measured from the instant of sunrise. The Solar constant is taken to be S_0 and the area of the solar panel A. Let θ be the instantaneous angle made by the sun with respect to the horizon as seen from the frame of reference of the solar panel and t be the instantaneous time $0 \leq t \leq T$.



4.1.1 The trivial case

The differential energy which reaches the solar panel at any time t is given by

$$dE_1 = S_0 A \sin\theta dt$$

$$\int_0^{E_1} dE_1 = \int_0^T S_0 A \sin(\omega t) dt$$

$$E_1 = \frac{S_0 A(1 - \cos(\omega T))}{\omega} \longrightarrow \boxed{1}$$

4.1.2 Our model

In our model θ is always equal to $\frac{\pi}{2}$. Hence, the differential energy which reaches the solar panel at any time t is given by

$$dE_2 = S_0 A dt$$

$$\int_0^{E_2} dE_2 = \int_0^T S_0 A dt$$

$$E_2 = S_0 A t \longrightarrow \boxed{2}$$

Dividing equations $\boxed{1}$ and $\boxed{2}$, we get

$$\frac{E_1}{E_2} = \frac{1 - \cos(\omega T)}{\omega T}$$

Plugging in $\omega = \frac{\pi}{T}$, we get

$$\frac{E_1}{E_2} = \frac{2}{\pi}$$

That is, $E_2 \approx 1.57E_1$. In other words, our model is roughly **57 percent more efficient** than the trivial scenario.

4.2 Calculating the time of luminescence of LED

Since the batteries we will be using are not ideal, we need to calculate exactly how long a battery will last with a load of constant power output. The following is the analysis:

1. The reserve capacity (RC) is a battery specification and is given as $7.5Ah$ (Ampere-hour).

2. Now the amount of energy (E) that is stored in the battery is given by the following expression $E = RC \times 60 \times 262.5$ Joules. Plugging in the values yields $E = 118125$ Joules. Therefore, a fully charged battery has 118125 Joules of energy stored.

3. Dividing E by the voltage rating of the battery will give us the amount of charge (Q) (in Coulombs) that is stored in the fully charged battery. Therefore $Q = E/V = 118125/12$ Coulombs $= 9843.75$ Coulombs.

4. Further dividing Q by the circuit current (I) will give us the time till discharging of the battery (T). However to calculate the circuit current we must first compute the LED resistance (R). To do so we need to divide the square of the voltage by the rated power output of the LED, these are given numbers. The computations yield $R = 18\Omega$.

Now the circuit current is given by $I = V/R = 12/18\ A = 0.67A$. Finally, the time till the discharging of the battery is $T = 9843.75/0.67$ seconds $= 14692.16$ seconds which is roughly 4 hours.

We conclude that the time a fully charged battery can run the LED is approximately **4 hours**.

Figure 1: Circuit Diagrams