Heliotropism of solar PV using the 4-bar mechanism analysis

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Abstract. Solar energy is the most abundant source of renewable energy upon which most conversions of energies could be possible. Solar tracking can be one method through which the energy reception could be increased. Heliotropism is a phenomenon that is observed in various botanical species like leaves, flowers, stems, etc, where there is reaction observed by various parts of the plant corresponding to a solar stimulus. The classic example of this phenomenon is the sunflower effect wherein the sunflower tends to orient itself towards the sun all throughout the day and receives maximum energy at its surface. Similarly, such an effect can be produced using the conventional four bar mechanism which would toggle around the spectrum of the sunlight received to at various positions at various durations of the day. This format of receiving energy would not only increase the quanta of packets being received on an average throughout the day but would also not waste the energy falling on the earth’s surface due to the misalignment of Photovoltaic (PV) cells usually installed in just one direction.

Keywords: Solar; Heliotropism, 4-bar mechanism, PV cells, Sunflower effect.

1. Introduction
As the world’s population inflation is at its never seen before increasing rate, so does the simultaneous need for the availability of the sustainable energy sources increases. There are various sources of energy both renewable and non-renewable. Non-renewable energy comes from a variety of sources such as natural gas, fossil fuels, coals etc. The depletion of such valuable energy sources is now at a high alarming rate and is degrading both climate as well as the vulnerability of mankind [1]. Despite it being a very valuable and rich source of energy there is continuously increasing demands for the potentially replenishable and renewable energy. The solar energy is one such abundant energy source that may not fade out in a faraway future and remain the best form of the ultimate source of energy. The Solar energy is an ultimate, continuous and a never-ending source of renewable energy and can be captured and converted into usable electricity by various methods. One such method is the usage of the PV cells where in the solar energy reflects onto the surface of the PV and that incident energy is converted into usable electricity. The solar energy reaching the surface converts as high as 30% of the energy into electricity and rest is reflected and absorbed by various water bodies [2]. The energy here however remains convertible to only that amount of time when the energy is directly falling over the solar PV. The rest energy is not taken into account. To solve this issue the modern-day concept of solar tracking and heliotropism is being employed. In this adopted method the aim is that the solar PV module or panel orients itself towards the direction of illumination so as to achieve the maximum energy incident to the surface of the PV cell. The heliotropism is majorly inspired from the sunflower effect wherein the
sunflower has its orientation towards the sun and keep receiving direct normal energy. This effect of response to solar stimulus is due to the plant hormone known as auxin and various other photoreceptors and is explained in detail in [3]. This type of a method is taken into account and various methods have been employed to achieve the heliotropism phenomenon in the conventional solar PV cells. One such method to achieve heliotropism in the solar PV cells is the usage of Carbon Nano Tubes (CNT) and the Liquid Crystalline Elastomer (LCE) to achieve the maximum power input. CNT and LTE have very good optical and thermal absorption respectively and can be used as self-tracking systems for the maximum power by the proposed mechanism in [4]. Another method of achieving the solar tracking system is by the microchip controller PIC 18F452 [5]. The system in here uses two different methods of solar tracking out of which the first method is the search mechanism (PILOT) and the other is the intelligent panels. Herein the method to achieve maximum energy output lies in the orientation of the PILOT. The intelligent panels only align themselves with the pilot if there is a maximum energy condition and this could happen only when the sun is facing towards the panel. There are various other methods of achieving this technique and another such method is by using the IBL 2403 drive unit [6], which connects to a dc motor and through the help of light intensity sensors the solar tracking could be achieved. These were some of the various methods by which the solar tracking could be achieved. In the current paper a different technique is adopted to incorporate heliotropism. Unlike the other stated few techniques, this doesn’t include any micro-controlling devices and is based on the conventional 4-bar mechanism. It works according to the Grashof law and the crank rocker mechanism is obtained. The solar panel’s motion is controlled by the rocker motion and it oscillates in the range where the maximum solar energy spectrum is obtained. This form of technique is different than most cases, as the energy obtained on the surface of the panel in them is due to the steady tracking whereas the mechanism followed here covers a spectrum of energy that falls on the surface of the panel. Here there is another feature, which distinguishes it from the general 4 bar mechanism. The toggling of the solar panel can be divided into three major segments wherein it would be oscillating in the bands of energy at various durations of the time of the day. All in all, it is another, not very efficient but an innovative way of tracking the solar energy and can be implied in regions abundant of maximum solar powers. The further sections discuss regarding the construction of the mechanism, operations of the mechanism, materials used in the mechanism and also the scope of future development and research can be seen.

2. Methodology

2.1. Working Requisites
The proposed mechanism should satisfy the following technical aspects under its working condition:

- The toggle obtained of the solar panel must be able to cover the entire spectrum of the energy falling over the PV panel
- The energy obtained through this method should be greater than the normal conventional installed solar PV cells.

2.2. Structural Setup
As stated above, that the mechanism obtained is the crank rocker mechanism, the structuring of the setup could be done in the following way:

- The entire mechanism is divided into 3-stage process where the rocker mechanism will be obtained at three different orientation depending upon the location of the sun.
- The major segment of time for the operation of the mechanism is considered to be between 8 A.M. to 5 P.M. where the Sun will be delivering maximum energy onto the Earth’s surface.
- According to calculations the rocker motion can be segmented into three slots of 45° each and that is divided into time slots of 3 hours each.
2.3. Constructional Aspects
For the construction of the mechanism, the following aspects need to be considered:

- The proposed mechanism is the 4-bar mechanism, wherein there is a crank, coupler, rocker and a fixed link.
- Since the link lengths need to be changed at various time slots, the crank, coupler and rocker are segmented.
- This segmentation can provide us with a suitable length configuration that can be applied to achieve the desired oscillation of the rocker between a particular location at a particular time.
- There are majorly 3 configurations that can be derived out of the setup as shown below.

2.4. Structural arrangements
The mechanism obtained should be majorly divided into 3 segments and the transition between each setup can be done manually. The 4-bar mechanism is arranged as follows:

- The fixed link is placed in the direction parallel to the rays of the sun.
- The crank depending upon the duration of the time can be attached to the fixed link at one end.
- Based on the design, the coupler and the rocker can be fixed.
- Finally, the rocker is connected at the end of the fixed link.
- An electric faculty such as a DC drive system can be applied to the crank, such that, a constant RPM of the crank is obtained.
- In correspondence to the same, the rocker mechanism toggles in an orientation based on its connection.

The detailed mechanism is shown in the next section.

3. Mechanism
The mechanism of the entire set up as discussed earlier can be broadly divided into three segments:

- 8 A.M. – 11 A.M
- 11 A.M. – 2 P.M
- 2 P.M – 5 P.M

The position of the sun in these intervals are broadly in three different positions as conventionally observed. Hence, to cover up all these segments, the extreme positions of the solar panel in the proposed mechanism are shown.

3.1. First Phase

These are the extreme positions in the automation and covers the maximum energy band falling on the surface of the earth. The energy obtained on the earth is assumed to be constant and around 1000 – 1300 kW. This configuration will only imply until the end of first hour, after which the configuration suitable to the next phase will have to be mechanised manually.
3.2. Second phase

The above images depict the extreme positions that can be employed during the second phase. The sun’s position is almost over head during this duration and the energy band obtained as per general observation are almost normal and high in both temperature and energy content. The toggling of the rocker almost covers the entire spectrum of band during the second phase interval. At the end of the second phase, the process will be needed to repeat of interchanging the links so as to obtain the 3rd inversion that follows next.

3.3. Third Phase

This the last phase that has to be employed after the second phase, and the extreme positions of the rocker are shown above. In this the evening spectrum is considered and the energy obtained in this phase is relatively lower. The mechanism can be further stopped as not much energy can be expected.

4. Scope of further research

The control of the crank in this case is by an electrical DC faculty and the transition of various phases is manual as of now. However various techniques can be employed to automate it. Some of them are as stated below:

- The usage of microprocessors in automating the crank and other transitions of the mechanism can reduce the mechanical operating of the system.
- Redesigning the segmentation and making it continuous and uniform in reference to the suns position using microcontrollers can evict the three stage system and the whole set up will be corresponding uniformly with the suns mean positioning.
• Addition of artificial intelligence to the core operation of the system to auto-calibrate it to the desired location can reduce all chances of energy losses.

In terms of design, there could be other permutations of linkage mechanism that could facilitate better toggling of the solar PV.

5. Conclusions

The paper proposes a way to provide a better surface area to the solar PV by the crank rocker mechanism of the 4-bar linkage system. It ensures that the entire band of useful energy is covered during the oscillatory movement of the rocker and no energy is much wasted. This action also helps in increasing the usability of the PV cell and also raises the amount of electrical energy so produced. The main components of the set up are the segmented bar mechanism that can be used in various configurations to attain the desired output angle of the rocker. The fundamentals behind the entire mechanism lies in the basic Grashoff’s law that provides this type of a suitable mechanism that is employed to gain the usability of the solar PV. This is one of the many ways to achieve the source concept of solar heliotropism.

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