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# Virtual prototyping of a solar tracking system

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## ABSTRACT
The subject of the seminar is now-a-days a priority on international level, because energy crisis is the most important issue in today's world. Conventional energy resources are not only limited but also the prime culprit for environmental pollution. Renewable energy resources are getting priorities in the whole world to lessen the dependency on conventional resources. Solar energy is rapidly gaining the focus as an important means of expanding renewable energy uses. It provides alternatives to major problems resulting from the use of fossil resources like the limitative character and pollution. But solar cells those convert sun's energy into electrical energy are costly and inefficient. Different mechanisms are applied to increase the efficiency of the solar cell to reduce the cost. Solar tracking system is the most appropriate technology to enhance the efficiency of the solar cells by tracking the sun.

**Keywords:** Solar Energy, Trackers, natural resource, automatic solar tracking

## 1. INTRODUCTION
There is a fact that the fossil fuels (ex., gas, oil, coal) are limited and hand strong pollutants. In the last 15 years, the price of petroleum had tripled and the previsions on the medium term there are not quite encouraging. The increase of the emissions of carbon dioxide, responsible for the global warming and for the greenhouse effect, may have devastating results over the time on the environment. The solution to the previously highlighted problems is the renewable energy, including the energy efficiency, the energy saving and systems based on clean renewable energy sources, like sun, wind and water. The concept of sustainable development have been enounced for the first time in 1987, in the Brundland Commission Report, and subsequent adopted at the political level, so in the Conference for

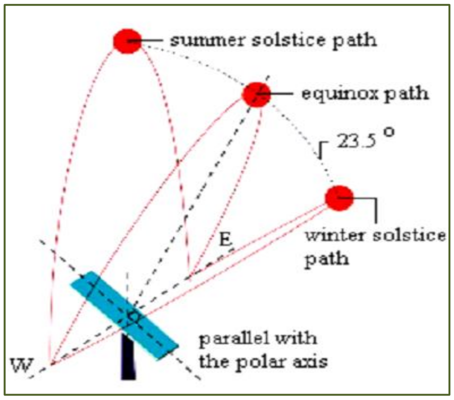


**Figure 1**
Solar orientation principle

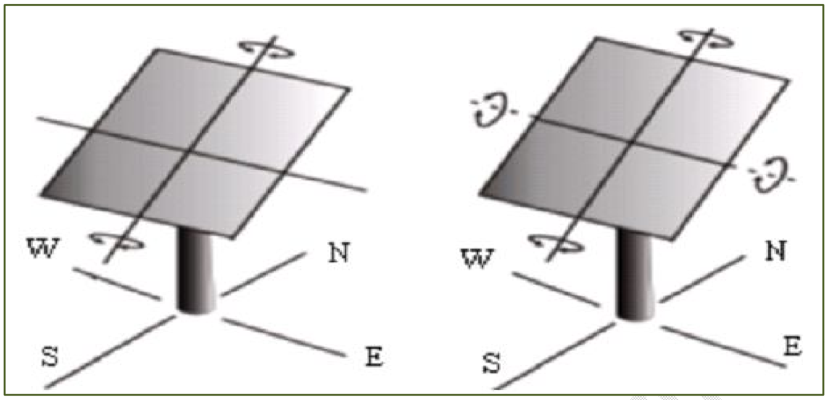


**Figure 2**
Basic Solar Tracker Systems

Development and Environment from Rio de Janeiro (1992), the participant countries have undertaken to develop national strategies for sustainable development. The instruments for the implementation of the concept are in continuous development and represents major directions for research in the European projects FP6 and FP7. The solar energy conversion is one of the most addressed topics in the fields of renewable energy systems. The sun is a giant nuclear fusion reactor and the energy it supplies is equivalent of about 27,000 times the total amount of energy presently produced from all other sources. As a result of the atmospheric phenomena involving reflection, scattering, and absorption of radiation, the quantity of solar energy that ultimately reaches the earth's surface is much reduced in intensity as it traverses the atmosphere. Finally, the total solar radiation received at ground level includes direct solar radiation and diffuse radiation. S P Sukhatme, "Solar energy", Book (1997).

## 2. SOLAR TRACKING SYSTEMS

"Clean Electricity from Photovoltaic" The efficiency of the solar system depends on the degree of use and conversion of the solar radiation. When performing the energy balance on the solar panel, reference is done to the surface that absorbs the incoming radiation and to the balance between energy inflow and energy outflow. The rate of useful energy leaving the absorber is given by the difference between the rate of optical (short wavelength) radiation incident on absorber and the rate of energy loss from the absorber. In these terms, there are two ways for maximizing the rate of useful energy: Optimizing the conversion to the absorber level, and decreasing the losses by properly choosing the absorber materials; increasing the incident radiation rate by using mechanical tracking systems (the maximum degree of collecting is obtained when the incident radiation is perpendicular on the active surface). Basically, the tracking systems are mechanical devices (i.e. mechanisms), driven by motors or actuators, which orient the panel in order to follow the sun path on the sky. The orientation of the solar panels may increase the efficiency of the conversion system up to 50%. The orientation principle is based on the input data referring to the position of the sun on the sky dome (Figure 1). For the highest conversion efficiency, the sunrays have to fall normal on the receiver so the system must periodically modify its position in order to maintain this relation between the sunrays and the panel. The positions of the Sun on its path along the year represent an input data in designing the solar trackers. The Earth describes along the year a rotational motion following an elliptical path around the sun. During one day (24 hours), the Earth also spins around its own axis describing a complete rotation, which generates the sunrises and the sunsets. The variation of the altitude of the sun on the celestial sphere during one year is determined by the precession motion, responsible for a declination of the Earth axis in consideration with the plane of the elliptic yearly path; the value of this angle is 23.5º (see (Figure 1)); this motion generates the seasons because of the alternative exposure of the northern and southern hemisphere to the sunrays trajectory. Consequently, for the design process of the tracking systems, these are taken into consideration two rotational motions: the daily motion (360º), and the yearly precession motion (2×23.5º). In these conditions, there are two fundamental ways to track the sun - by one axis, or by two axes. This fact determines two types of solar tracking systems (Figure 2): single axis (a), and dual-axis trackers (b). The two-axis trackers combine two rotational motions, so that they are able to follow very precisely the sun path along the period of one year. That's why dual axis tracking systems are more efficient than the single one, but also more expensive because they are using electrical and mechanical parts. In this case, there are two independent motions: the daily motion, and the seasonal motion, respectively.

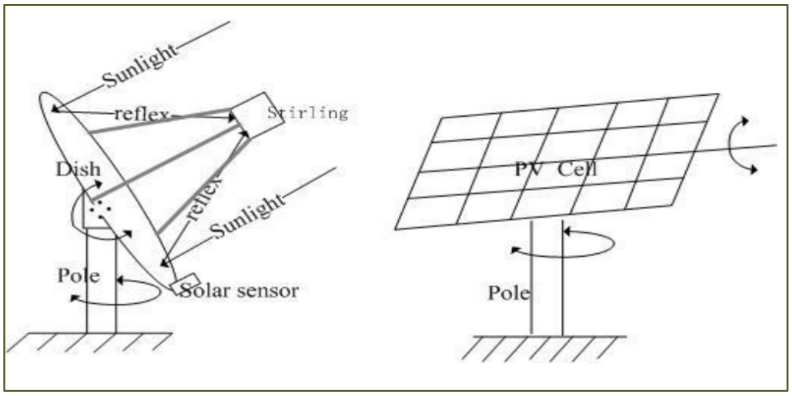


**Figure 3**

Automatic Sun Tracking System—Dishes and PV

**Figure 4**

Active Tracker

**Figure 5**

Passive Tracker

In remote areas the sun is a cheap source of electricity because instead of hydraulic generators it uses solar cells to efficiency; the solar panels must remain in front of sun during the whole day. But due to rotation of earth those panels can't maintain their position always in front of sun. This problem results in decrease of their efficiency. Thus to get a constant output, an automated system is required which should be capable to constantly rotate the solar panel. The Sun Tracking System (STS) was made as a prototype to solve the problem, mentioned above. It is completely automatic and keeps the panel in front of sun until that is visible. "The unique feature of this system is that instead of taking the earth as its reference, it takes the sun as a guiding source. Its active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum." In case the sun gets invisible e.g. in cloudy weather, then without tracking the sun the STS keeps rotating the solar panel in opposite direction to the rotation of earth. But its speed of rotation is same as that of earth's rotation. Due to this property when after some time e.g. half an hour when the sun again gets visible, the solar panel is exactly in front of sun. Moreoverthe system can manage the errors and also provides the error messages on the LCD display. In manual mode, through the software (GUI) at computer, the solar panel can be rotated at any desired angle (Figure 3).

## 3. NEED OF TRACKING SYSTEM

Global warming has increased the demand and request for green energy produced by the renewable sources like solar power. The end user will prefer the tracking solution rather than a fix ground system because:

- The efficiency increases by 30 to 40% (=more money).
- The space requirement for a solar park is reduced, and they keep the same output.
- The return of the investment timeline is reduced.
- The tracking system amortises itself with four years (on avg.).
- Tracking the sun from east in the morning to the west in the evening will increases the efficiency of the solar panel by 20 to 62% depending on whom you ask and where you are in the world. Near the equator, you will have the highest benefit of tracking the sun.

## 4. SOLAR TRACK DRIVE TYPES

There are mainly three different types of drive system based upon the principle we are using to drive the track system.

### 4.1. Active Tracker

Active tracker use motors and gear trains to direct the tracker as compared by a controller responding to the solar direction. Active to axis trackers are also use to orient heliostats- movable mirrors that reflects sun light toward the absorber of a central power station. As each mirror in a large field will have an individual orientation these are controlled programmatically through a central computer system, which also allows the system to be shut down when necessary. Light sensing trackers typically have to photo sensors, such has photo diodes, configured differentially so that they output null when receiving the same sun light flux. Since the motors consume energy, one wants to use them only as necessary. So instead of continuous motion, the heliostat is move in discrete steps. Also, if the light is below some threshold there would not be in a power generated to warrant reorientation. This is also true when there is not enough difference in light level from one direction to another such as when clouds are passing over head. Consideration must be made to keep the tracker from wasting energy during cloudy period (Figure 4).

### 4.2. Passive Tracker

The above figure shows the passive tracker drive system. It is used lower boiling point compressed gas fluid that is prevent to one side or the other (by solar heat creating gas pressure)to causes the tracker to move in response to an imbalance. As this is known precision orientation its un suitable for certain types of concentrating PV collectors but work fine for common PV panel types. This will have viscous dampers to prevent excessive motion in response to wind gusts. Reflectors are used to reflect early morning sun light to wake up the panel and tilt it toward the sun, which can take nearly an hour. The time to do this can be greatly reduced by adding a self-releasing tie down that positions the panel slightly pass the zenith (so that the fluid does not have to overcome the gravity) and using the tie down in the evening. The term passive tracker is also used for PV modules that include a hologram behind stripes of PV cells. That way, sun light passes through the transparent part of the module and reflects on the hologram. This allows sun light to heat the cell from behind, thereby increasing modules efficiency. Also the module doesn't have to move since the hologram always reflects sun light from the correct angle toward the cells (Figure 5).

### 4.3. Chronological Tracker

A chronological counter act, the earth's rotation by turning and equal rate as the earth, but in opposite direction. Actually the rates are not equal, because as the earth goes around the sun, the position of the sun changes with respect to the earth by 360˚. Every year or 365.24 days a chronological tracker is a very simple yet potentially a very accurate solar tracker especially for use with a polar mount. The drive method may be as simple as a gear motor that rotates a very slow avg. rate of 1 revolution per day (15 degree/hour). In theory the tracker may rotate completely, assuming there is in a clearance for a complete rotation, and assuming that wires are not an issue, such as with a twisting solar concentrator, or the tracker may be reset each day to avoid these issues alternatively an electronic controller may be use, with a real time clock use to infer the solar time (hour angle).

## 5. MAIN COMPONENT OF SOLAR TRACKING SYSTEM

There are mainly five components for a general Solar tracking system these are:

- Solar panel
- Motor
- Sensors
- Solar Tracker
- Microcontroller

### Solar panel

Solar panels are devices that convert light into electricity. They are called solar after the sun or "Sol" because the sun is the most powerful source of the light available for use. They are sometimes called photovoltaic which means "light-electricity". Solar cells or PV cells rely on the photovoltaic effect to absorb the energy of the sun and cause current to flow between two oppositely charge layers (Figure 6). A solar panel is a collection of solar cells. Although each solar cell provides a relatively small amount of power, many solar cells spread over a large area can provide enough power to be useful. To get the most power, solar panels have to be pointed directly at the Sun. The development of solar cell technology begins with 1839 research of French physicist Antoine-Cesar Becquerel. He observed the photovoltaic effect while experimenting with a solid electrode in an electrolyte solution. After that he saw a voltage developed when light fell upon the electrode. According to Encyclopedia Britannica the first genuine for solar panel was built around 1883 by Charles Fritts. He used junctions formed by coating selenium (a semiconductor) with an extremely thin layer of gold. Crystalline silicon and gallium arsenide are typical choices of materials for solar panels. Gallium arsenide crystals are grown especially for photovoltaic use, but silicon crystals are available in less-expensive standard ingots, which are produced mainly for consumption in the microelectronics industry. Norway's Renewable Energy Corporation (REC) has confirmed that it will build a solar manufacturing plant in Singapore by 2010 - the largest in the world. This plant will be able to produce products that can generate up to 1.5 gigawatts (GW) of energy every year.

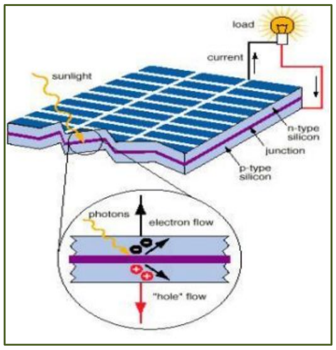


**Figure 6**
Solar Panel

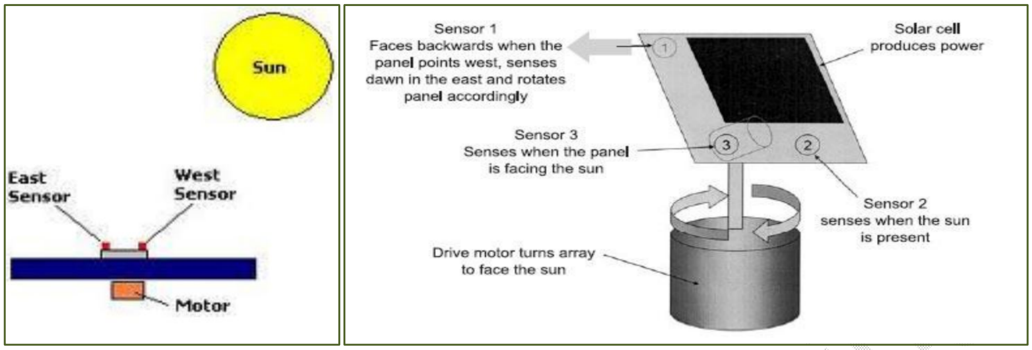


**Figure 7**
Working of solar tracking systems

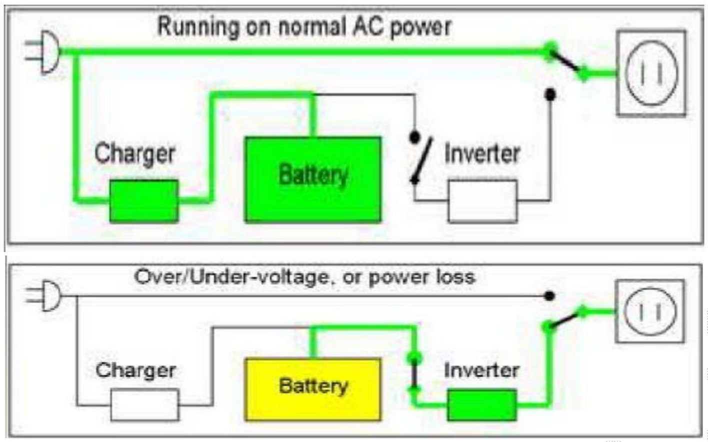


**Figure 8**
Comparisons of different working conditions

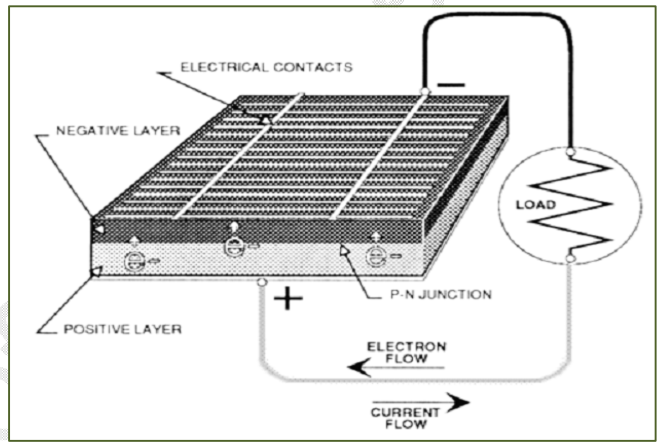


**Figure 9**
Flow directions of electrons and current

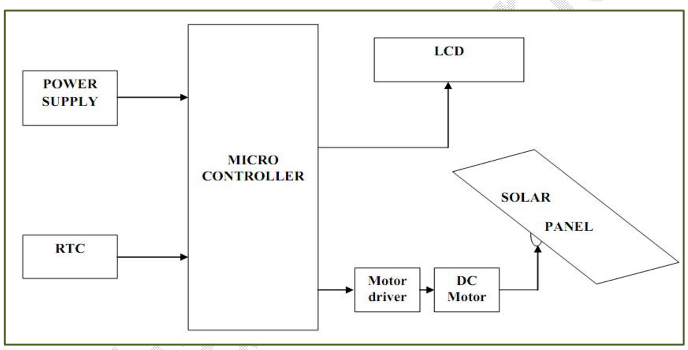


**Figure 10**
Block diagram of the solar tracking unit

That is enough to power several million households at any one time. Last year, the world as a whole produced products that could generate just 2 GW in total.

## Sensors

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument Light Dependent Resistor. Light Dependent Resistor (LDR) is made of a high-resistance semiconductor. It can also be referred to as a photoconductor. If light falling on the device is of the high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance. Hence, Light Dependent Resistors (LDR) is very useful in light sensor circuits. LDR is very high-resistance, sometimes as high as 1000 000Ω, when they are illuminated with light resistance drops dramatically.

## Solar Tracker

Solar Tracker is basically a device onto which solar panels are fitted which tracks the motion of the sun across the sky ensuring that the maximum amount of sunlight strikes the panels throughout the day. After finding the sunlight, the tracker will try to navigate through the path ensuring the best sunlight is detected. The design of the Solar Tracker requires many components. The design and construction of it could be divided into six main parts, each with their main function.



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### Motors

#### Stepper Motors

Stepper motor has relatively limited power which means that wheel spin will not be a problem. It is not fast but it will work. The driver chips are operated by two signals. One signal determines the direction of rotation, plus for forward and minus for backwards. The other moves the stepper by one step each time it goes from minus to plus. Stepper motors move in steps, 200 or 400 steps per revolution to be precise. To move them, the stepper driver firmware had to have a smooth pulse. If the pulse timing is out, the motor would just stop and not move. They can also produce precise motor rotation if the correct motor driver firmware signals are obtained.

#### DC Motors

DC motors are cheaper to buy, and simple to drive but they need feed-back sensors to allow control of the speed. It is necessary to detect the rotation of the wheels, usually by means of sensors better controlled by pulling the motor supply that uses less battery power than the analogue/resistor methods. Low-inertia, efficient servo-motors bring advantages of fast response and efficiency, but add cost. The advantages of the DC motor are the torque and their speed is easier to control. The drawbacks of DC motors are that they consumed huge amounts of power. They would consumed the battery power in no time and power saving techniques must be employed to ensure the mouse do not stop halfway while navigating. They are also prone to dust and harder to maintain.

#### Servo Motors

Servos contain a small DC motor, a gearbox and some control circuitry, and feed on 5 volts at about 100mA maximum, and about 10-20mA when idle. They have a three-wire connector, one common wire (0 volt, usually black), one +5v wire (usually red), and one signal wire. In normal use they are controlled by pulses of about 1 to 2 milli-seconds at a repetition rate of about 50 per second. A short pulse makes the servo drive to one end of the travel, a long pulse makes it drive to the other end, and a medium one puts it somewhere proportionally between. Some servos have gear components that allow them to rotate continuously. This method needs the servo to have a feedback potentiometer used by internal circuits to measure the position of the output shaft. If this is disconnected and the wires taken to an external pre-set potentiometer, the servo will drive continuously in one direction if fed with short pulses and vice-versa. If there are no pulses, the servo stops. It is uses to drive the Solar Tracker Eastward and Westward. The pulses are at normal TTL levels. The speed though, is not greatly affected by the pulse repetition rate, as long as it is above about 30 per second. These pulses can easily be provided by an output port of just about any computer, for instance the data or control lines of a printer port or a serial port, or a simple addressed latch added to the memory circuits. A possible configuration is the tricycle described above, with one driving and steering-wheel at the front and two idler wheels at the rear. Using a Radio Controlled (RC) servo for steering is a good method, because the position of the steering mechanism is determined by the length of the servo drive pulse, which can be generated by a software countdown loop or a hard-ware counter. If an RC servo is used as a drive motor, wheel motion sensors are needed on at least one wheel as in any DC motorsystem. The use of an RC servo for driving only simplifies the mechanics. In summary, servos are very small and precise motors.

## 6. WORKING OF SOLAR TRACKING SYSTEM

P. Roth et al., (2004) given the working principal of solar tracking system. The procedure as follows:

- First we arrange LDR perpendicular to direction of solar rays. So LDR only catch the direct radiation from the sun.
- Because of the direct radiation more photon produces emf due to photo electric effect.
- Position of LDR as shown in figure 7.
- When the sun catches the direct radiation than the circuit is in off condition.
- But when sun moves from its place, LDR not catch any beam radiation and circuit comes in ON condition.
- Solar rays imparted on the PV cell directly covering its max. Area.
- Due to the pv effect the current produce in the circuit and this current is saving in the battery (Figure 8).
- The photoelectric effect relies on the principle that whenever light strikes the surface of certain metals electrons are released.
- In the p-n junction the n-type wafer treated with phosphorus has extra electrons which flow into the holes in the holes in the p-type layer that has been treated with boron.
- Connected by an external circuit electrons flow from the negative side to create electricity and end up in the positive side (Figure 9).
- Sunlight is the catalyst of the reaction.
- The output current of this reaction is DC and the amount of energy produced is directly proportional to the amount of sunlight put in.
- Cells only have and average efficiency of 30%.



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Construction and Working of the circuit:

Now we have three parts which are connected to main control circuit.

- 1st part is output from panel to battery input and battery to control circuit
- 2nd part is to rotate the motor; battery output is connected to circuit to control the motor.
- 3rd part is a direct output from a battery to our useful work (Figure 10).
- As shown in above figure when, the circuit is in the OFF position as mentioned above, in this position the power from the battery is supply power to the motor.
- As due to power supply to the motor, motor rotates the shaft which is connected to the disc on which the solar plate is mounted.
- Thus solar plates also rotate with shaft rotations and the LDR fixed with it.
- This rotation is on forward direction taking place as backward is restricted by us
- While panel rotates as LDR is come perpendicular to the sun direct beam direction its intensity becomes maximum again, and circuit again comes to off position.
- And this position plates held steady of rotation stop.
- As the sun changes its place this process repeats throughout the day.
- As the sun set the intensity of LDR is minimum thus whole proceeds now stops for next day.
- We have used only one way current flow from plate to battery
- Thus, as per the direction of the sun the sensors are arranged that it will catch only maximum sun intensity to produce the maximum efficiency of the system.
- The rotating direction of the LDR is controlled by the motor. So it will either clockwise or the anticlockwise as per the direction of the sun rays throughout the day.

## 7. ADVANTAGES

### The conservation of non-renewable energy resources

Photovoltaic (PV) solar power eases the usage of diminishing natural resources such as oil, coal and gas. Today, we live in an exceptionally demanding environment where the use of energy is growing at an alarming rate. It is vital to preserve the earth's fossil fuels and other natural resources, not only for a healthier environment but also for the ability of future generations to meet their own needs.

### Lower Rates of Waste and Pollution

PV solar power systems minimize the amount of waste production. For example, the entire process of converting coal to electricity produces a lot of dust, discarded solid waste, spillages of toxins and harmful emissions, as well as wasting energy, heat, land and water. Pollution from non renewable fuels is inevitable. Emissions such as Sulphur Dioxide, Nitrogen Oxide and Carbon Dioxide all can have a negative effect on farming, people's health and water. Ecosystems are also at risk of being destroyed. Furthermore, pollutants from kerosene used for lighting purposes is reduced with the use of solar power systems, as well as the decrease in use of diesel generators for the production of electricity.

### Offsetting Green House Gases

PV Solar power systems produce electricity without giving off carbon dioxide. One PV Solar system can offset approximately six tons of $CO_2$ emissions over a twenty year life span.

### Reduction of Energy Usage

Solar power improves energy efficiency and is therefore very beneficial for Third World countries. Solar power electricity reduces the costs of conventional power for built up cities, and is cheaper for industrial and commercial purposes to run their operations. This leaves the use of PV systems to generate power for most of the developing world's population in rural areas.

### Decrease in Disposing of Dry-Cell Batteries

Small dry cell batteries are used for appliances such as portable radios and flashlights, but are most commonly used in rural areas where there is lack of electricity .However, the lead from these disposed dry cell batteries can have damaging effects on soil and water. Solar power reduces the need of using disposable dry cell batteries and therefore decreases the risk of contamination.

- Simple low profile design with fewer parts.
- Requires minimal field leveling and site preparation
- Easy rapid installation.
- Return to sun rise position automatically.

### Limitations

- Trackers add cost and maintenance to the system - if they add 25% to the cost, and improve the output by 25%, the same performance can be obtained by making the system 25% larger, eliminating associated maintenance
- When there is cloudy atmosphere it is difficult to tracking the sun.
- Panel rotations require a extra power from outside of power used that produce by panel itself.
- Fixing arrangement of LDR at perpendicular to sun light is somewhat problematic.

### Applications

- Single axis tracking system for use with conventional solar modules, pv thermal models and concentrator.
- Perfect for supplying power to remote radio and communication posts and water pumps.
- Perform well as mounts for residential PV system.

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