# Proposed Ways to Extract Maximum Efficient Power Out Of a Solar Panel

**N.Gopi Chand, K.Ravi Teja, M.Sridevi**

***Abstract*--*In this paper,we presented how to extract maximum efficiency out of a solar panel using two combined techniques. The first one we have to implement is a micro-controller based solar-tracking system. The system checks the position of the sun and controls the movement of a solar panel so that radiation of the sun comes normally to the surface of the solar panel and the second is to install an MPPT charge controller which makes the inverter to work at maximum power point. so that under any climatic conditions maximum power is extracted. This way we make efficient use of both solar panel and solar-energy from sun.***

***Index Terms*-- *MPPT(Maximum power point tracking), Charge Controller, Micro-controller, Solar Tracking.***

## I. INTRODUCTION

The panels are the fundamental solar-energy conversion component. Conventional solar panels, fixed with a certain angle, limits their area of exposure from the sun during the course of the day. Therefore, the average solar energy is not always maximized. Solar tracking systems are essential for many applications such as thermal energy storage systems and solar energy based power generation systems in order to improve system performance

Solar panels have a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP), which depends on the environmental factors, such as temperature and irradiation. In order to continuously harvest maximum power from the solar panels, they have to operate at their MPP despite the inevitable changes in the environment. This is why the controllers of all solar power electronic converters employ some method for maximum power point tracking (MPPT). Over the past decades many MPPT techniques have been published. The algorithms that where found most suitable for large and medium size photovoltaic (PV) applications is incremental conductance

The change in sun's position is monitored, and the system always keeps that the plane of the panel is normal to the direction of the sun. By doing so, maximum irradiation and thermal energy would be taken from the sun. The elevation angle of the sun remains almost invariant in a month and varies little (latitude ± 10°) in a year. Therefore, a single axis position control scheme may be sufficient for the collection of solar energy in some applications Efficient collection of maximum solar irradiation on a flat panel requires adjustments of two parameters of the energy collecting surface namely the angle of azimuth, ψ and the angle of tilt , α This paper deals with controlling the solar panel at two axis (or two angles) by using LDR's as sensors,stepper motors as actuators (SM1, SM2) and micro

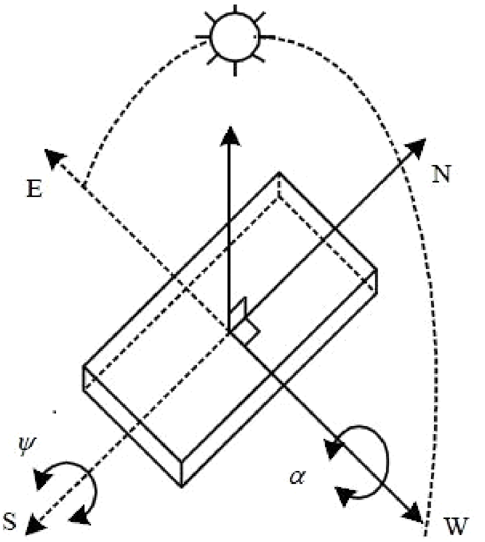


Fig. 1 Two axis position control of the solar panel

controller as a controller. In order to keep the design as simple and cheap we have chosen PIC16C71 as a micro-controller-unit (MCU). In addition to this, to observe position of the solar panel, PC based system monitoring facility is included in the design as shown in Fig. 2. The efficiency of a PV plant is affected mainly by three factors: the efficiency of the PV panel (in commercial PV panels it is between 8-15% ), the efficiency of the inverter (95-98 % ) and the efficiency of the *maximum power point tracking* (MPPT) algorithm (which is over 98% ). Improving the efficiency of the PV panel and the inverter is not easy as it depends on the technology available, it may require better components, which can increase drastically the cost of the installation.

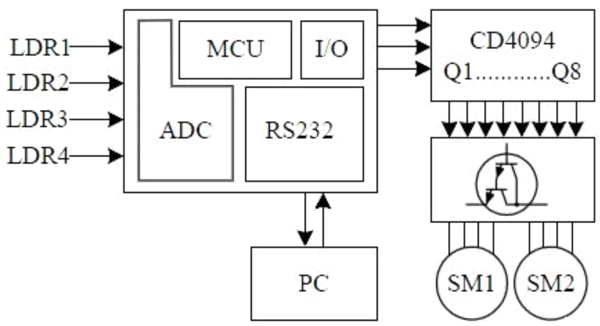


Fig. 2 Block diagram of the proposed solar tracking

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Instead, improving the tracking of the *maximum power point* (MPP) with new control algorithms is easier, not expensive and can be done even in plants which are already in use by updating their control algorithms, which would lead to an immediate increase in PV power generation and consequently a reduction in its price. MPPT algorithms are

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necessary because PV arrays have a non linear voltage-current characteristic with a unique point where the power produced is maximum. This point depends on the temperature of the panels and on the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year. Furthermore, irradiation can change rapidly due to changing atmospheric conditions such as clouds. It is very important to track the MPP accurately under all possible conditions so that the maximum available power is always obtained.

Maximum point tracker to operate at maximum power point we need the input of currents and voltage.

## II. OPEN CIRCUIT VOLTAGE, SHORT CIRCUIT CURRENT AND MAXIMUM POWER POINT

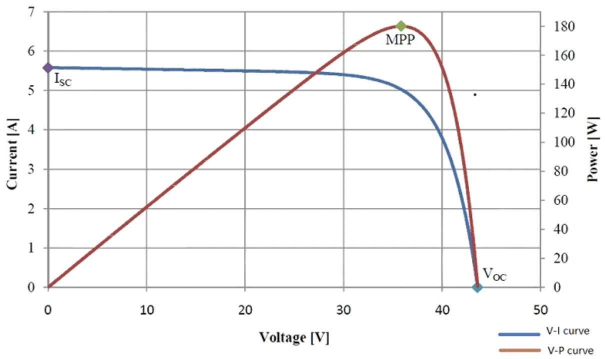


Figure 3 – Important points in the characteristic curves of a solar panel.

Two important points of the current-voltage characteristic must be pointed out: the open circuit voltage *VOC* and the short circuit current *ISC*. At both points the power generated is zero. *VOC* can be approximated from (1) when the output current of the cell is zero, i.e. $I$=0 and the shunt resistance *RSH* is neglected. The short circuit current *ISC* is the current at $V$ = 0 and is approximately equal to the light generated current *IL* as shown in equation (1).

$$V_{OC}(T) = V_{oc}^{STC} + \frac{K_{V,\%}}{100}(T - 273.15) \quad \text{— (1)}$$

The maximum power is generated by the solar cell at a point of the current-voltage characteristic where the product *VI* is maximum. This point is known as the MPP and is unique, as can be seen in Figure 3, where the previous points are The maximum power is generated by the solar cell at a point of the current-voltage characteristic where the product *VI* is maximum. This point is known as the MPP and is unique, as can be seen in Figure 3,

## III. TEMPERATURE AND IRRADIANCE EFFECTS

Two important factors that have to be taken into account are the irradiance and the temperature. They strongly affect the characteristics of solar modules. As a result, the MPP varies during the day and that is the main reason why the MPP must constantly be tracked and ensure that the maximum available power is obtained from the panel.

The effect of the irradiance on the voltage-current (V-I) and voltage-power (V-P) characteristics is depicted in Figure 4, where the curves are shown in per unit, i.e. the voltage and current are normalized using the *VOC* and the *ISC* respectively, in order to illustrate better the effects of the irradiance on the V-I and V-P curves. As was previously mentioned, the photo-generated current is directly proportional to the irradiance level, so an increment in the irradiation leads to a higher photo-generated current. Moreover, the short circuit current is directly proportional to the photo generated current; therefore it is directly proportional to the irradiance. When the operating point is not the short circuit, in which no power is generated, the photo generated current is also the main factor in the PV current, as is expressed by equations (1) and (2).

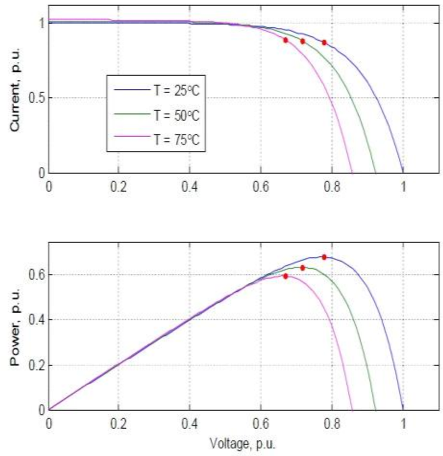


Figure 5 - V-I and V-P curves at constant irradiation (1 kW/m²) and three different temperatures.

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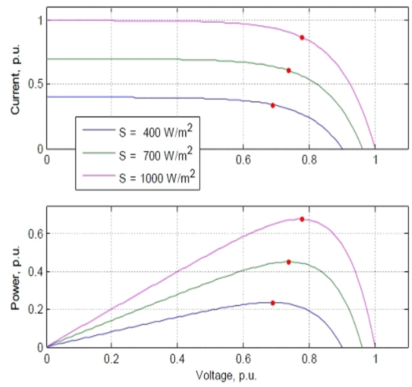



Figure 4 - V-I and V-P curves at constant temperature (25°C) and three different insolation values.

For this reason the voltage-current characteristic varies with the irradiation. In contrast, the effect in the open circuit voltage is relatively small, as the dependence of the light generated current is logarithmic, as is shown in equation (4). Figure. 4 shows that the change in the current is greater than in the voltage. In practice, the voltage dependency on the irradiation is often neglected . As the effect on both the current and voltage is positive, i.e. both increase when the irradiation rises, the effect on the power is also positive: the more irradiance, the more power is generated. The temperature, on the other hand, affects mostly the voltage. The open circuit voltage is linearly dependent on the temperature, as shown in the following equation-2.

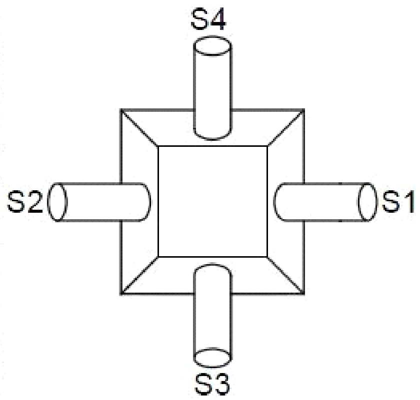
$$V_{OC} \approx \frac{AkT}{q} ln\left(\frac{I_L}{I_0} + 1\right) \quad \text{—(2)}$$

According to (6), the effect of the temperature on *VOC* is negative, because *Kv* is negative, i.e. when the temperature rises, the voltage decreases. The current increases with the temperature but very little and it does not compensate the decre ase in the voltage caused by a given temperature rise.

That is why the power also decreases. PV panel manufacturers provide in their data sheets the temperature coefficients, which are the parameters that specify how the open circuit voltage, the short circuit current and the maximum power vary when the temperature changes. As the effect of the temperature on the current is really small, it is usually neglected. Figure 5 shows how the voltage-current and the voltage-power characteristics change with temperature. The curves are again in per unit, as in the previous case.

## IV. DESIGN OF THE SOLAR TRACKING SYSTEM

The tracker control system contains a control board,a control program, a power supply board, one motor interface board and a set of sensors. The main idea of design of the solar-tracking system is to sense the sun light by using four light dependent resistors

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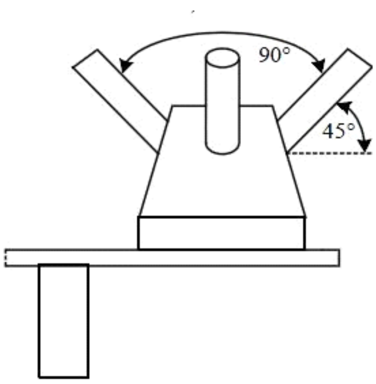
(LDRs). Each LDR is fixed inside the hallow cylindrical tubes. A pair of them, controlling the angle of azimuth, are positioned East-West direction and the two of them, controlling the angle of tilt, are positioned South-North direction. The LDR assembly is fixed onto the flat-solar panel, shown in Figure 3. The tubes are making a degree of 45° with the plane of panel; so, the angle between the tubes is 90°.




b)

The differential signals of each pair of LDRs representing the angular error of the solar panel are employed to re-position the panel in such a way that the angular errors are minimized. A micro-controller system with PIC16C71 used as the controller of the position control scheme offers up to 10MHz clock frequency, four ADC channels with 8-bit, 1Kx14 EPROM memory and thirteen I/O ports (Anon., 1998a). Since the apparent speed of the sun is very slow, the panel will also move very slowly. Therefore, a crystal with a frequency of 4MHz is used as a clock signal generator for MCU. The signals, taken from voltage divider consisting of resistors and LDRs (S1, S2, S3, S4), are applied to I/O port lines of MCU (RA0, RA1, RA2, RA3) respectively. These analog signals are converted to digital signals and compared with each others (S1-S2, S3-S4).

If the difference between S1 and S2 (or S3 and S4), error signal, is bigger than a certain value (tolerance), MCU generates driving signals for stepper motors. If the error signals are smaller than or equal to the value of tolerance, MCU generates no signal; which means that the solar panel is facing the sun and the light intensities falling on the four LDRs are equal or slightly different. Schematic representation of the solar-tracking system is given in Fig. 4. In order to drive two-stepper motors, an 8-bit shift register CD4094 is used . Data is shifted serially through to shift register on positive transition of the clock signals generated by MCU.

Four-output signals (Q1, Q2, Q3, Q4) drive the first stepper motor and the rest of the signal (Q5, Q6, Q7, Q8) drive the second-stepper motor. In this system, eight darling ton transistors (TIP122) are used to drive the SMs. The control commands generated by MCU for driving of SM's and positioning of the solar panel are given in Table 1. As can be seen from the Table 1, when SM2 is driven, four-driving signals for SM1 is set (1111XXXX), and vice-versa. The software is developed in an assembly programming language.It is compatible for PIC16C71 and is a machine level language. The software consists of a main module and a few subroutines. Simplified flowchart of the assembly program is given in Figure 5b, where *e* denotes error(tolerance)The stepper motors requires a +9V supply and four control pulses at its terminals. One step angle of the

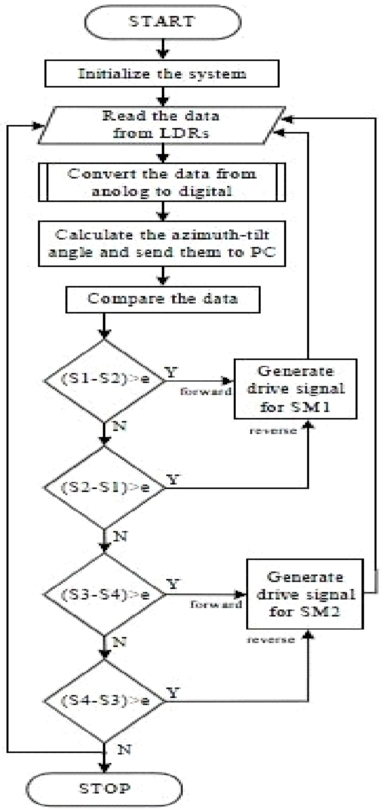



Figure 5b Simplified flowchart of the assembly program

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Table 1. The control Commands for Stepper Motors

| STEPPER MOTOR 1 | | STEPPER MOTOR 2 | |
|---|---|---|---|
| Q1-Q2-Q3-Q4-Q5-Q6-Q7-Q8 | | | |
| Forward | Reverse | Forward | Reverse |
| 0001-1111 | 1000-1111 | 1111-0001 | 1111-1000 |
| 0010-1111 | 0100-1111 | 1111-0010 | 1111-0100 |
| 0100-1111 | 0010-1111 | 1111-0100 | 1111-0010 |
| 1000-1111 | 0001-1111 | 1111-1000 | 1111-0001 |

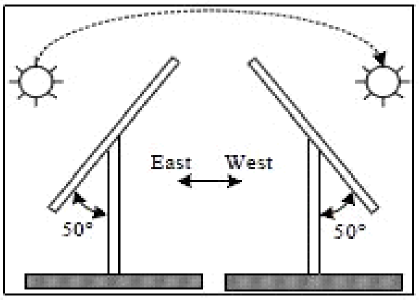


Figure 6. Limits for movement of the solar panel

motor is equal to 1.8°. If the difference between S1 and S2 is grater than the error, the first stepper motor should rotate forward; if the difference between S2 and S1 is grater than the error, it should rotate reverse direction. Same procedure is applied for the second stepper motor. In order to prevent the flat panel hitting to body, the panel is limited as vertically with a degree of 50° (Figure 6). Thus, the azimuthal drives can rotate on a total of degree of 260° during day times.

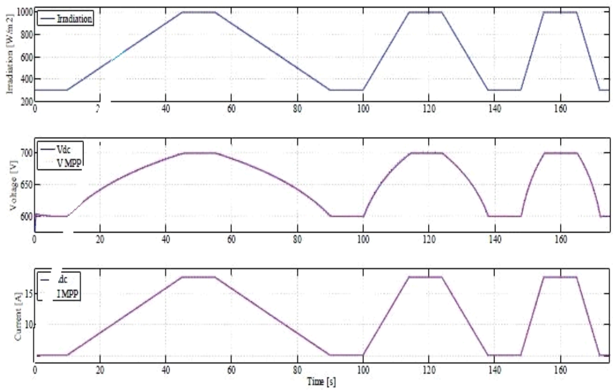


fig. 8 Increemental Conductance MPPT algorithm dynamic efficiency test. The algorithm tracks the MPP under the irradiation slope proposed in the standard.

In general applications, the panel should be rotated towards East direction in order to make it ready for operation on the next day. The proposed system sends no signals during night times by sensing low or none sunshine intensities and stays as pointing at west direction after the sun set. The micro-controller unit is also skipped to sleep mode and consumes low energy.During the sun rise, the LDR senses the sunlight automatically and the panel is moved towards Figure 7 .A photograph of the proposed solar tracker-system body.

## V. INCREMENTAL CONDUCTANCE ALGORITHM

East direction in a short time; so, there is no need any extra circuitry and software to do this. A photograph of the proposed solar-tracker-system body used in experimental studies is given in The algorithm used for maximum power point tracking is incremental conductance.

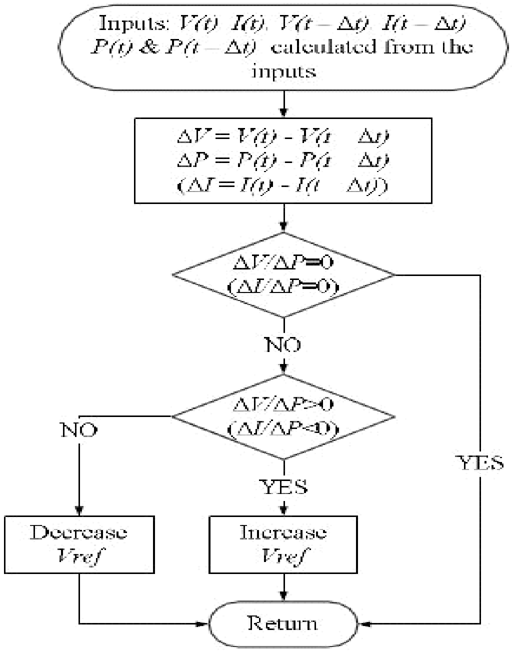


Figure.7 Incremental conductance algorithm

## VI. EXPERIMENTAL RESULTS

The results of the mpp tracker using the incremental conductance are shown below.

The solar tracking system presented here is tested experimentally. Two solar collector panels, one of which is stationary and the other is rotary, are employed in the test. The stationary panel is tilted at a fixed elevation angle **Proposed ways to extract maximum efficient power out of a solar panel.**

and is oriented in some azimuth angle. The LDRs assembly is mounted on the rotary one. Temperature of the panels versus time is measured with a minute interval of 11.75' in the period 7:48 to 17 : 24. So, a total of measurement time is 9:36'. In this interval, a total of 50 data were captured from the stationary panel and the rotary panel with approximately an angle interval of 5.2°. The measurement results are given in Figure 8. The differences between the temperature of rotary panel and that of stationary one are also given as graphically in Figure 8.

According to the results: while the sun rises in the morning, the temperature of each panel also increases linearly and the difference is almost constant until about 11 o'clock because of being illuminated from the sun with different azimuth and tilt angle (ψ ,α ). After this point, the temperature of panels decreases until about 11:30 due to weather condition. The temperature, then, increases to the normal condition again, and then keeps decreasing slightly afternoon. The temperature of average value of the stationary panel between the hours of 7 : 48 and 17 : 24 is measured as 34.9 °C and that of the rotary panel is 43.88 °C. It is very obvious that there is approximately a distinction of 9 °C between rotary and stationary panel. This result shows and verifies that the rotary panel containing solar tracking system takes more light density than the stationary panel

## VII. CONCLUSION

In order to collect the greatest amount of energy from the sun, solar panels must be aligned orthogonally to the sun. For this purpose, a new solar tracking technique based on micro-controller was implemented and tested in this study. The tracking system presented has the following advantages: The tracking system is not constrained by the geographical location of installation of the solar panel since it is designed for searching the maximum solar irradiance in the whole azimuth and tilt angle (except hardware limitations ) during day times; namely, the angle of elevation does not need to be adjusted periodically. The operator interference is minimal because of not needing to be adjusted. The tracker provides also PC based system monitoring facility. Since the tracking system is controlled completely by MCU; the PC, used for monitoring the panel only, may not be employed. A drawback of the tracker is being effected by temporal variations in the atmospheric refractions caused by rain, cloud, fog, etc. Thus, the system may give an erroneous detection in the direction of the sun, and lead to wrong positioning of the solar panel.other proposed technique is using an MPPT . By using a mppt the dynamic efficiency measured according the standard was above 99.4 %.two parameters which effect the maximum power output of a solar panel are irradiance and temperature these two parameters under different conditions are analyzed.

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