EFFICIENCY IMPROVEMENT OF PHOTOVOLTAIC PANEL BY TRACKING METHOD

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***Abstract*- Due to the limited supply of non-renewable fuels, to find the alternative of new energy resources is essential. Besides, fossil fuels have many side effects such as acid rain and global warming. Therefore, conversion to clean energy sources such as solar energy would enable the world to improve the quality of life throughout the planet Earth. With economic development and growing demand for energy, conventional energy sources have become increasingly unable to meet the world demand for energy and they are depleting day by day so the awareness of global warming and increasing prizes of fossil fuels has drawn more attention towards the usage of renewable energy sources today. Renewable energies are the better solution for our health and the health of our earth; it is just the future source of energy! Sustainable energy sources like solar, wind, and fuel cells are becoming increasingly important as environmental friendly alternatives to the traditional energy sources. Among the various renewable energy systems, solar energy systems have the merits such as it is abundant, clean without any environmental pollution problems and infinite in mass so becoming one of the future energies. In Solar, Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it exhibits many merits such as cleanness, little maintenance and no noise. However, these environmental friendly sources are difficult to tap, store, and use. Successful application of these sustainable sources depends on being able to maximize efficiency in both conversion and energy storage. But we have to improve the rate and optimize this source. The dual maximization scheme presented utilizes two techniques of maximizing available solar energy. In usual residential applications solar panels are kept fixed at a particular tilt angle. This limits the area of exposure of PV panels to sun over entire course of day and will generate maximum power only for a short time of span, from 11am to 2pm. solar energy available during rest of the day is not extracted at its maximum. In a system where we need maximum possible efficiency, this usual method will not be applicable. The proposed system not only extracts maximum power using MPPT, but also from the mechanical tracking system for the whole day from 6am to 6pm.While the mechanical tracking is not only the solution because it only tracks the sun position and doesn't response to change in atmospheric condition and solar Insolation. So electrical tracking is used which compare the energy produced with the rating of solar panel for which it is designed. So electromechanical tracking of PV panel improves efficiency. The partial shading effect causes the Hot spot which may burn cell. By using bypass diode implantation it can be mitigate but it creates the local and global maxima. So electrical tracking fails to indentify the true or global maxima. So different partial shading mitigation techniques are used in conjunction with electrical tracking.**

Keywords*- *PV panel, MPPT, dual axis tracking, incremental conductance method, partial shading.

II. PROBLEM OVERVIEW

The problem considered by MPPT techniques is to automatically find the voltage V_{MPP} or current I_{MPP} at which a PV array should operate to obtain the maximum power output P_{MPP} under a given temperature and irradiance. It is noted that under partial shading conditions, in some cases it is possible to have multiple local maxima, but overall there is still only one true MPP. Most techniques respond to changes in both irradiance and temperature, but some are specifically more useful if temperature is approximately constant. Most techniques would automatically respond to changes in the array due to aging, though some are open-loop and would require periodic fine-tuning. In our context, the array will typically be connected to a power converter that can vary the current coming from the PV array.

I. INTRODUCATION

A simple equivalent circuit model for a photovoltaic cell consists of a real diode in parallel with an ideal current source as shown in Figure1

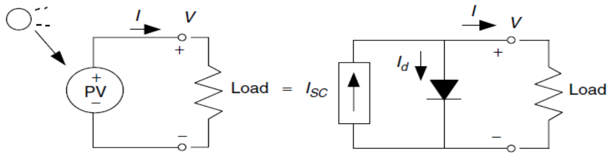

Figure1.1: A simple equivalent circuit for a photovoltaic cell consists of a current source driven by sunlight in parallel with a real diode. [1]

The I-V characteristic of a solar panel is given by figure 1.3

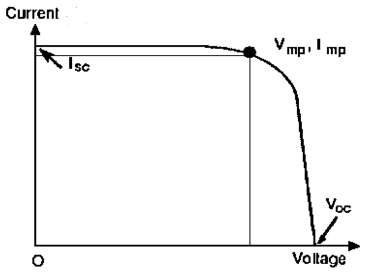

Figure 1.2 I-V characteristic of a solar panel

When the voltage and current characteristic are multiplied; we get the P-V characteristics as shown in figure 1.3

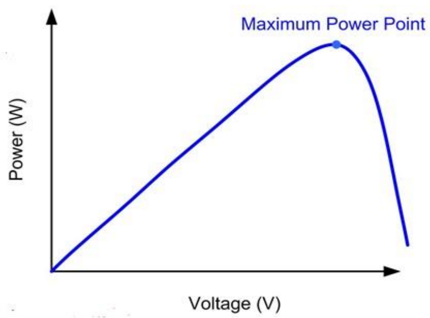

Figure 1.3 P-V characteristic of a solar panel

II. MAXIMUM POWER POINT (MPP)

Solar energy is the energy extracted from the sun rays issued from the sun in the form of heat and electricity. This energy is essential for all life on earth. It is renewable resource that is clean, economical, and less pollution compared to other resources and energy. So solar energy is rapidly gaining popularity as compared to other renewable energy sources. The installation cost of PV panel along with the other accessories is more. Successful application of PV panel depends upon then it efficiency and energy storage. In such case, the output of PV panel must be more so that it will be economical and beneficial for consumer to use it. In general, PV generation systems have two major problems; the conversion efficiency of electric power generation is low (in general less than 17%, especially under low irradiation conditions), and the amount of electric power generated by solar arrays changes continuously with weather conditions. [2]. The output current vs. voltage curve of a photovoltaic cell shows a non-linear characteristic. From this nonlinear relationship, it can be observed that there is a unique point, under given illumination and temperature, at which the cell produces maximum power, the so-called maximum power point (MPP). As shown in figure 1.4 This point occurs when the rate of change of the power with respect to the voltage is equal to zero. The output power of PV cell varies with depending mainly on the level of solar radiation and ambient temperature corresponding to a specific weather condition. The MPP will change with external environment of PV cell. An important consideration in achieving high efficiency in PV power generation system is to match the PV source and load impedance properly for any weather conditions, thus obtaining maximum power generation. The tracking process of maximum power point is called maximum power point tracking (MPPT). Due to a nonlinear current voltage characteristic of PV cells, it is difficult to track the MPP. The situation gets worse when the solar irradiance and/or cell operating temperature changes. Numerous techniques have been proposed so far to realize MPP. [3]

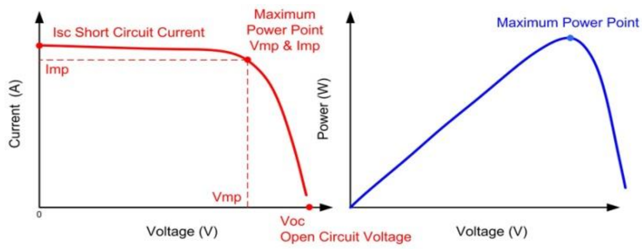

Figure 1.4 P-V characteristic of a solar panel

III. MECHANICAL TRACKING

Solar tracker is a device used to orient a solar panel towards the sun. Since the sun’s position in sky changes with the time of the day, solar tracker is used to track the maximum amount of light produced by the sun. It is discovered that the instantaneous solar radiation collected by PV array modules, assembled in tracking system, is higher than in fixed systems. It is estimated that the yield from solar panels can instead of a stationary array. Up to 40% extra power can be produced per annum using a variable elevation solar tracker. [4] So solar tracking system with sun-tracking capabilities, because the positioning accuracy of solar tracking system improves the energy collection of the whole system. There are different models of mechanical tracking systems. The single axis solar tracker follows the sun usually from East to West during the day (Horizontal

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axis solar tracker). a dual axis tracker maintains the solar receiver surface to the optimal position(perpendicular to the sun light) and allows collection of the maximum possible amount of energy. [5] Two axis solar tracker or dual axis solar tracker can increase the energy conservation by 40% by keeping the panels pointing towards the maximum sun radiation during the entire day. Dual axis tracking system, based on an open loop system where the tracker operates based on mathematical calculation according to the sun's geometry to predict the exact apparent position of sun. In dual axis mechanical tracking; the panel is rotated in x – axis (360 degree) and in y-axis (180 degree). The solar Zenith angle is defined as the angle between the central ray from the sun, and a horizontal plane containing the observer. The solar azimuth angle is the angle, measured clockwise on the horizontal plane, from the north-pointing coordinate axis to the projection of the sun's central ray. The tilt angle is the zenith angle and rotation angle is the azimuth angle [6]. These both angels show the sun's position from observer. By using the GPS, sun's exact position can be tracked and it can be stored in Personal computer for one month and after each month it can be updated. While the system without GPS proves more efficient because it can track the sun's position when it changes and no up gradation is required like GPS.

III. MECHANICAL TRACKING WITHOUT GPS

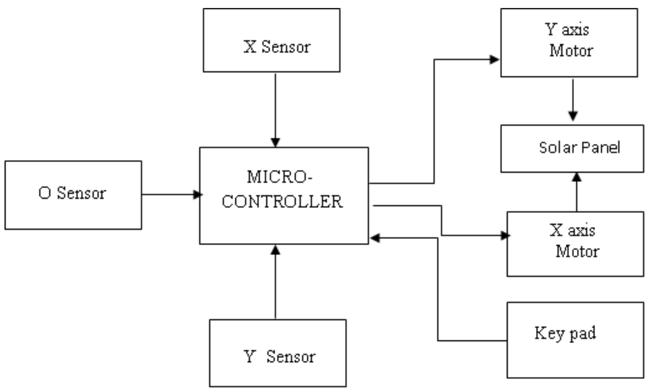

Figure. 1.5 Layout of Dual Axis mechanical tracking

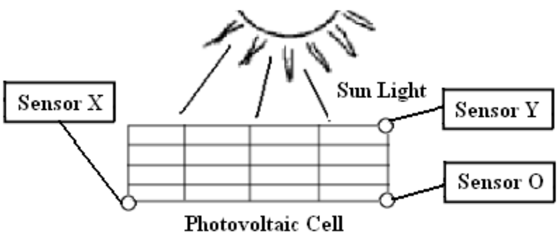

Figure-1.6 Three photoresistors installed on PV

Three photoresistors are used in the tracking system all are fixed on the upper part of the system near the photovoltaic cell in an X-O-Y manner as shown in figure 1.6. It allows a reference photoresistors the one at position O which will be compared with the photoresistors X and Y and depending on the voltage output. The tracker will compare X and O positions, the comparison will end after a very near values of outputs of those two photoresistors are reached, a loop will control the stepper motor motion and steps till a near equality of sunlight distribution will be reached. After reaching an acceptable position and values for the X-O position test, the Y-O photo resistors are tested and compared in the same manner.[7]

When the system is started the output values of the sensors will be compared together in order to locate the light direction. If the output of the sensor X is greater than that of sensor O then the system will deviate toward X, the system will rotate in the x-y plane, in order to reach a value where the two sensors have nearly the same output voltage. The same operation is done for the z-plane, as the sensor O and X have a similar output voltage then, a comparison with the Y sensor will allow the system to rotate in the z-plane. Using this method the tracker will have the sun position. This position will be updated each time a variation will occurs in the outputs of the sensors , the time of updating the track can be regulated (knowing that the deviation of the sun will not occurs each second), so a period time can be added once the system is in stable position in order to reach the second stable position . The benefit of the smart tracker is that allows a precise position of the sun light. The sun direction is measured in a three axis diagram (position and angle). The information that the tracker will detect will be sent to different systems that has the same functionality (that rotates following the solar rays to reduce the power consumption of the system.[7][8][12]

IV ELECTRICAL TRACKING

The mechanical tracking fails under the change in solar irradiation and change in temperature. So electrical tracking is used in conjunction with the mechanical tracking. During clouds though sun's position is tracked mechanical tracking will fail. The purpose of electrical tracking is to track the MPP by varying the duty cycle of DC-DC buck boost converter. There are mainly 9 and distinct 35 methods to track MPP by electrical tracking. Some major methods are perturb and observed method or Hill climbing method, incremental conductance method. Fractional open circuit and fractional short circuit current method, fuzzy logic and artificial neural network method. The fuzzy logic and ANN gives the true MPP and does not oscillate about the true MPP while other methods oscillate about true MPP so that methods are not efficient.

V. INCREMENTAL CONDUCTANCE

The incremental conductance (IncCond) method is based on the fact that the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by

$$\frac{\mathrm{dp}}{\mathrm{dv}} = 0 \qquad \text{at MPP}$$

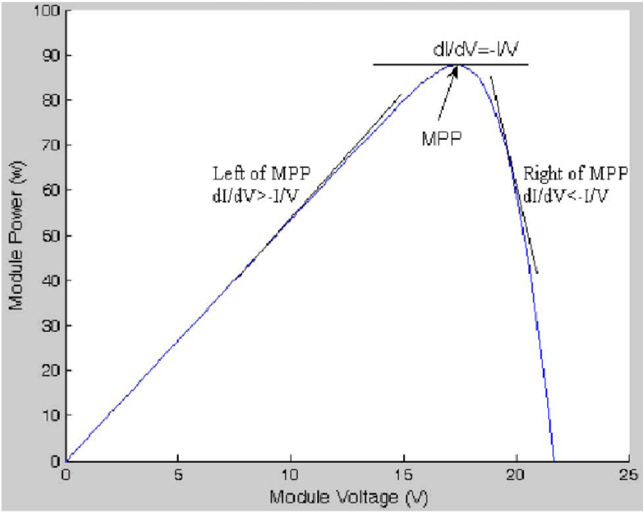

Figure 1.7 –Basic Idea of the Incremental Conductance method on a P-V curve Of a Solar Module

$$\frac{\mathrm{dp}}{\mathrm{dv}} > 0 \quad left\ of\ MPP \qquad (1.1)$$

$$\frac{\mathrm{dp}}{\mathrm{dv}} < 0 \quad right\ of\ MPP \qquad (1.2)$$

Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} = I + V\frac{\Delta I}{\Delta V}$$

So equation (1.1) can be written as

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} \qquad \text{At MPP}$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V} \qquad \text{left of MPP}$$

The MPP can thus be tracked by comparing the instantaneous conductance (*I/V*) to the incremental conductance ($\Delta I/\Delta V$) as shown in the flowchart in Fig.2.1 *Vref* is the reference voltage at which the PV array is forced to operate. At the MPP, *Vref* equals to *VMPP*. Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in ΔI is noted, indicating a change in atmospheric conditions and the MPP. The algorithm decrements or increments *Vref* to track the new MPP.[13]

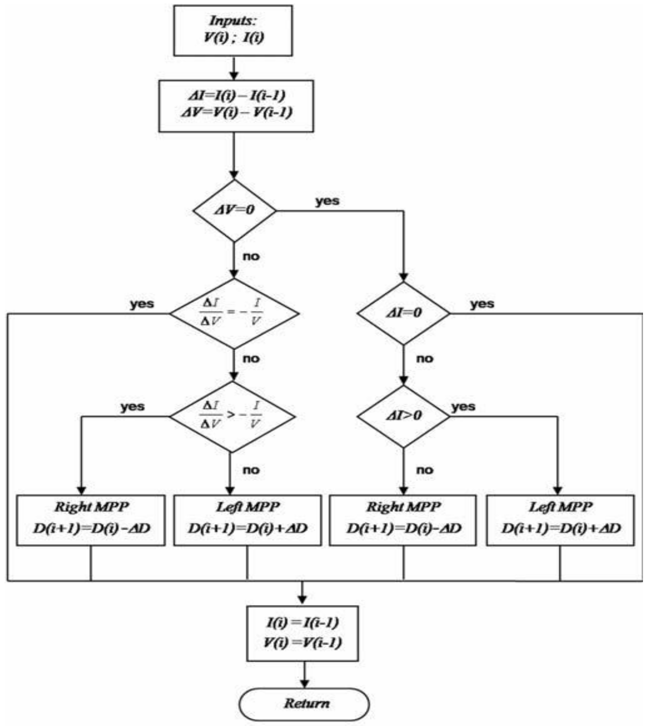

Figure 1.8 Flowchart of Incremental conductance method

V. ELECTROMECHANICAL TRACKING

The efficiency of Photovoltaic panel can be improved more by combining the electrical and mechanical tracking. The complete layout of system is shown in figure 1.9. it consist of two microcontroller, one is for mechanical tracking and other is for electrical tracking. When the light is incident on photovoltaic panel, the sensor senses the light and gives analogue input to microcontroller which converts it into the digital form. Microcontroller runs the algorithm to find the highest input of light. After the execution of algorithm, microcontroller gives command to stepper motor to rotate the panel to obtain the maximum sun light. The output of microcontroller is not that much sufficient to rotate the panel using stepper motor. So stepper motor driver is used which convert the few ampere input into the large output to rotate the motor. Sometimes instead of stepper motor, DC motor or DC motor with servo mechanism is used but the inertia of DC motor is high which may cause the problem to track the sun’s exact position. Stepper motors are specially designed for the precise position control. In this way the mechanical tracking is done. Output of battery charger is given to both microcontrollers which is nothing but the voltage and current at which Photovoltaic panel must be operate. Electrical tracking uses another microcontroller and DC to DC buck boost converter with battery charger.

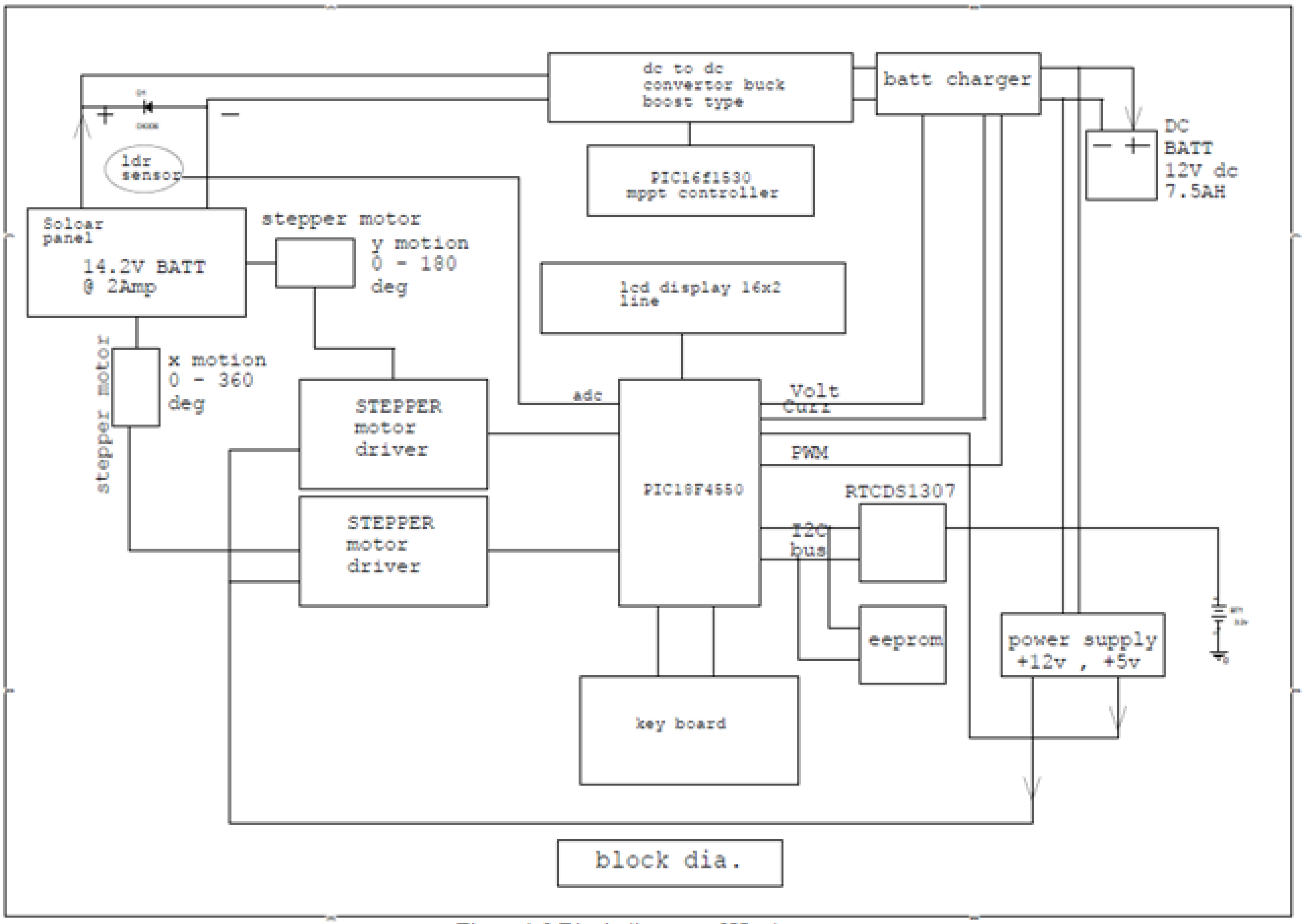

Figure 1.9 Block diagram of Hardware

The microcontroller PIC 18F4550 is used for mechanical tracking while the microcontroller PIC16f1530 is used for electrical tracking. As mechanical tracking microcontroller has the inbuilt analouge to digital converter which convert the analogue signal of light into the digital which is compatible to microcontroller.th user can connect microcontroller to PC for programming. The EEPROM is used to store the data. The whole system is independent on external supply system. The energy generated by PV panel is feed to drive the microcontroller as well as motor. The real time clock is used to provide the date and time and sun's exact position during the day. Both the electrical and mechanical tracking improves efficiency up to 50% while electrical tracking with mechanical tracking can improves the efficiency up to 70 to 75%.

V. CONCLUSION

Mechanical tracking improves the efficiency of PV panel but it fails under the change in solar irradiation and atmospheric condition. While electrical tracking overcome the this problem and track the MPP under change in solar irradiation. DC to DC buck boost converter may face problem because of continuous change in duty cycle. Change in duty cycle is entirely dependent on a switching or firing of IGBT or MOSFET. So sufficient time lag or delay must be provided to the converter by doing programming in microcontroller.

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