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Maximum Power Point Tracking Scheme for PV Systems Operating Under Partially Shaded Conditions.

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ABSTRACT. The performance of a photovoltaic (PV) array is affected by temperature, solar insulation, shading, and array configuration. Often, the PV arrays get shadowed, completely or partially, by the passing clouds, neighbouring buildings and towers, trees, and utility and telephone poles.
Under partially shaded conditions, the PV characteristics get more complex with multiple peaks. This makes the tracking of the actual maximum power point (MPP) a difficult task. In this paper, a simple technique of MPPT is presented for photovoltaic power generation system to solve the aforementioned problems. It realizes simple control system to track the real maximum power point even under non uniform or for rapidly changing insulation conditions.

Key words*:* Photovoltaic (PV) array, MATLAB Simulink, Maximum Power Point Tracking (MPPT)

1. INTRODUCTION

Renewable energy sources such as solar energy are acquiring more significance, due to shortage and environmental impacts of conventional fuels. The photovoltaic (PV) system for converting solar energy into electricity is in general costly and is a vital way of electricity generation only if it can produce the maximum possible output for all weather conditions. In general, a PV source is operated in conjunction with a dc– dc power converter, whose duty cycle is modulated in order to track the instantaneous MPP of the PV source. The output of the PV depends highly on an insulation condition and a surface temperature of the PV array. Moreover, there are several local maximum power points in the P-V curve under non-uniform insulation, whereas only one MPPT point is exist under uniform insulation for a given temperature and insulation. Several tracking schemes under uniform solar insulation have been proposed. Among the popular tracking schemes are the perturb and observe (P&O) or hill climbing, incremental conductance, short circuit current , open-circuit voltage , and ripple correlation approaches . Some modified techniques have also been proposed, with the objective of minimizing the hardware or improving the performance.

However, these methods cannot readily track immediate and rapid changes in environmental conditions or non-uniform insulation of the PV modules.

The non-uniform insulation of the PV modules which are connected both in series and in parallel depends on several factors such as the incidence angle of solar ray to the module, shadows full-or-partial, and so forth. Under partially shaded conditions, (e.g., due to clouds, trees, etc.), the P–V characteristics get more complex, displaying multiple peaks. There is a need to develop special MPPT schemes that can track the true MPP under these conditions. In order to solve this problem, several methods have been proposed.

Several MPPT techniques and circuit configuration methods for improving the efficiency of PV system have been reported in the literature. Many technical papers discussed the MPPT techniques, but most of the review papers mainly considered the MPPT methods for normal radiation condition. Besides the normal MPPT schemes, the important and practically viable MPPT techniques have been presented in this paper.

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2. SOLAR PHOTOVOLTAIC SYSTEM

A PV cell is basically a p-n junction semiconductor which converts parts of solar radiation into electricity. Typical voltage and current of PV cell are very low, so multiple cells are connected in series and parallel form to increase the rating and known as a module. Similarly, number of PV module connected in series and parallel fashion, is known as PV array. The PV panel is a radiation control current source in parallel with diode and loss resistance. A single diode mathematical model of PV module is shown in Fig. 1

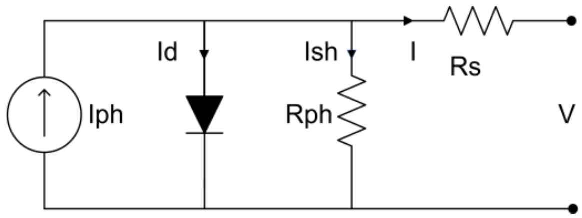

Fig. 1 Single diode PV model

Where Id the diode is current, Rph is the shunt resistance; Iph is the light generated current of solar array. Solar cell is basically a p-n junction fabricated in a thin wafer or layer of semiconductor. The electromagnetic radiation of solar energy can be directly converted electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor are absorbed and create some electron –hole pairs Proportional to the incident irradiation. Under the influence of the internal electric fields of the p-n junction, these carriers are swept apart and create a photocurrent which is directly proportional to solar insolation. PV system naturally exhibits a nonlinear I-V and P-V characteristics which vary with the radiant intensity and cell temperature.
It shows that if fixed resistance is connected across the PV array then point of operation is depends upon the load resistance and Irradiance level. For MPP operation, the optimal resistance needs to connect across the PV array. Generally, the load or battery rating is fixed, and environment condition varies rapidly. The MPPT is used to operate PV system at points.

The MPPT techniques make the use of algorithm and electronic circuit for maximum power extraction. The MPPT works to match the impedance of load and PV system. The impedance matching is carried out by using DC-DC converter, whose duty cycle is adjusted in a manner to make the value of apparent load across the PV array, equivalent to optimal load

The advantages of solar panels are,

- They are the most readily available solar technology.
- They can last a lifetime.
- They are required little maintenance.
- They operate best on bright days with little or no obstruction to incident sunlight.

3. MPPT ALGORITHM USING PARTIALLY SHADED CONDITION

MPPT control has been proposed and implemented for extracting the maximum power from the PV cell. PV array voltage (i.e. incrementing or decreasing) and comparing the PV output power with that of the previous perturbation cycle. If the perturbation leads to an increase/decrease in array power, the subsequent perturbation is made in the same/opposite direction. In this manner, the peak power is tracked continuously. But this algorithm has two weaknesses.

- When shading occurs, the reversal of the voltage can be observed in that specific section and now the bypass diode in parallel will conduct the current. The results are:
- the current of the un-shaded section flows through the bypass diode and the power/voltage characteristic shows a second local maximum
- the shaded cell is only loaded with that fraction of power produced by the remaining unshaded cells of that section
- when the number of cells which are bridged by the by-pass diode is not too high, the level of the breakthrough voltage will not be reached.

But there are also some draw backs resulting from the by-pass diodes: Higher cost for the module production and assembly problems of the by-pass diodes. Losses in the by-pass diode in the case of shading.

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4. PERTURBATION AND OBSERVATION (P&O) TECHNIQUE

In this method the controller adjusts the voltage by a small amount from the array and measures power, if the power increases, further adjustments in the direction are tried until power no longer increases. This is called P&O method. Due to ease of implementation it is the most commonly used MPPT method.
The P&O is a most widely used MPPT technique. As the name suggest, first it perturbs the variable either voltage or current and then observes the optimization quantity P (Power). Based upon the response, the controller
Either increase or decrease the value of V or I.. Now, controller changes the reference voltage by changing the duty cycle of the dc-dc converter in one direction and check corresponding V2, I2 and P2. If P2 is greater than P1, then direction of perturbation is correct, otherwise change the direction of Δd. At maximum power point, dP/dV is approximately equal to zero. However in practical, the point of Vmpp is hard to calculate and operating point oscillates near MPP. To reduce oscillation near MPP, Δd must be as small as possible, but it increases the tracking time. So, it is essential to choose the optimal step size of duty cycle (d).

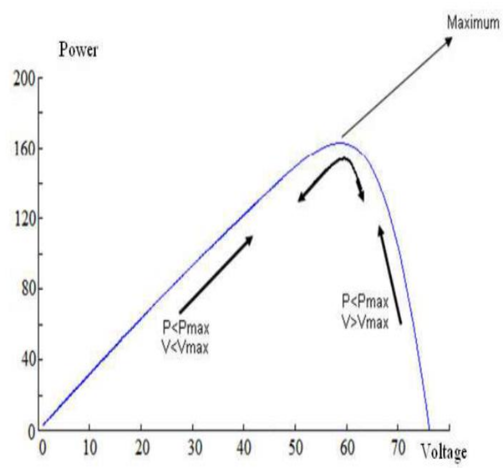

Fig.2 Outputpower using P&O algorithm

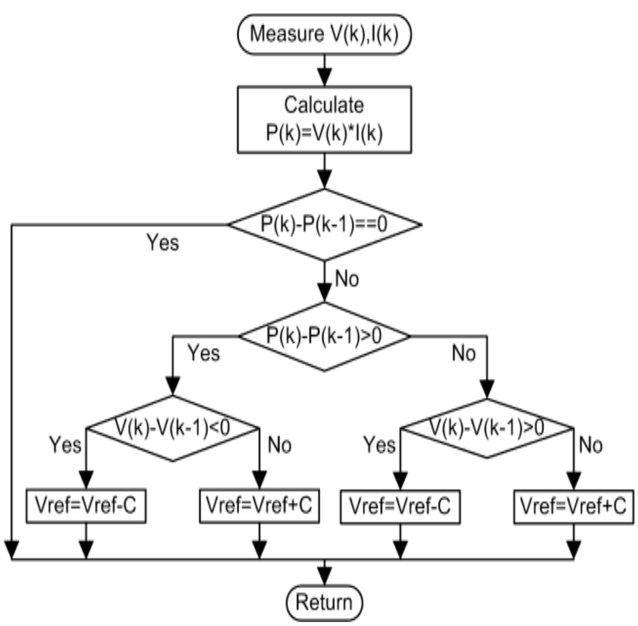

Fig. 3 Algorithm of P&O MPPT technique

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Benefits:

P&O is very popular and most commonly used in practice because of
1. Its simplicity in algorithm.
2. Ease of implementation.
3. Low cost
4. It is a comparatively an accurate method

Drawbacks:

There are some limitations that reduce its MPPT efficiency. They are,

1. It cannot determine when it has actually reached the MPP. Under steady state operation the output power oscillates around the MPP.

5. DC-DC CONVERTER

A DC-DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. The DC-DC converters are widely used in regulated switch-mode dc power supplies and in dc motor drives applications. Often the input of these converters is an unregulated dc voltage, which is obtained by rectifying the line voltage, and therefore it will fluctuate due to changes in the line voltage magnitude. Switch-mode DC-DC converters are used to convert the unregulated dc input into a controlled dc output at a desired voltage level. The heart of MPPT hardware is a switch-mode DC-DC converter.

MPPT uses the converter for a different purpose: regulating the input voltage at the PV MPP and providing load matching for the maximum power transfer.

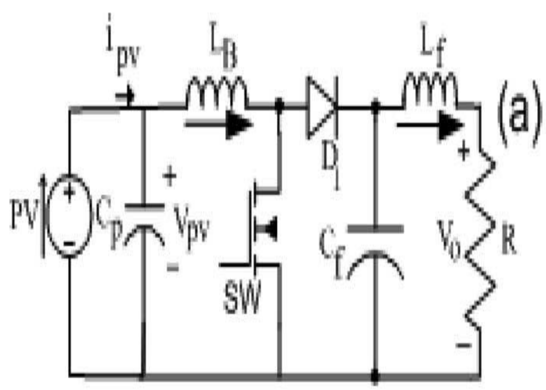

Fig.4 Circuit schematic for boost converter used for tracking MPP.

Fig.4 shows the circuit schematic of a boost-type dc–dc power converter whose duty cycle is modulated as per the algorithm used for electrical tracking of the MPP.

In a conventional controller working with the P&O method, duty cycle ($D*$) is generated as follows:

$$D* = 1 - (V_{ref} / V_o)$$

Where V_{ref} is the reference voltage obtained using the MPPT algorithm and V_o is the output voltage of the dc–dc converter. It is observed that such a controller is slow to respond. The proposed controller overcomes this drawback. Here, the control signal for dc–dc converter is obtained in a feed forward manner, as shown in the figure.4 .The controller is fast to respond and can quickly track the MPP.

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6. Simulation Model and Output Waveform

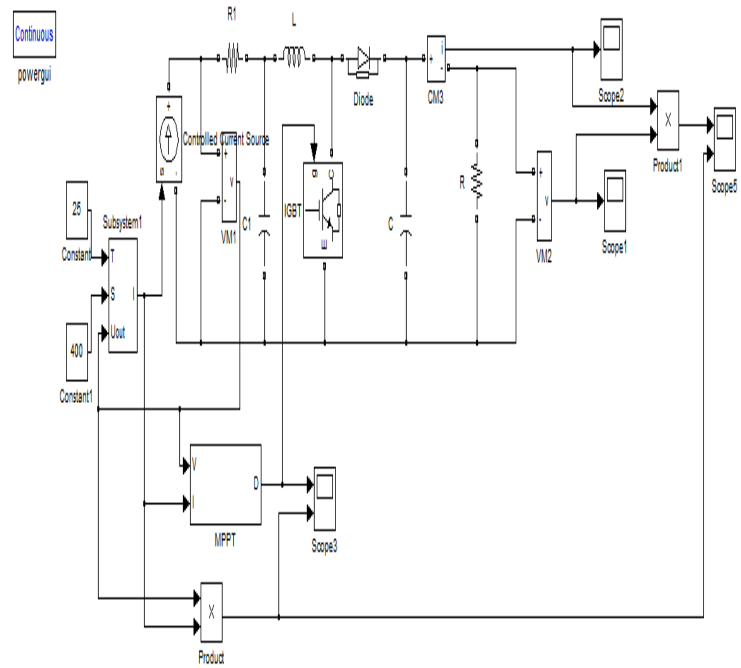

Fig.5 PV array with partial Shading

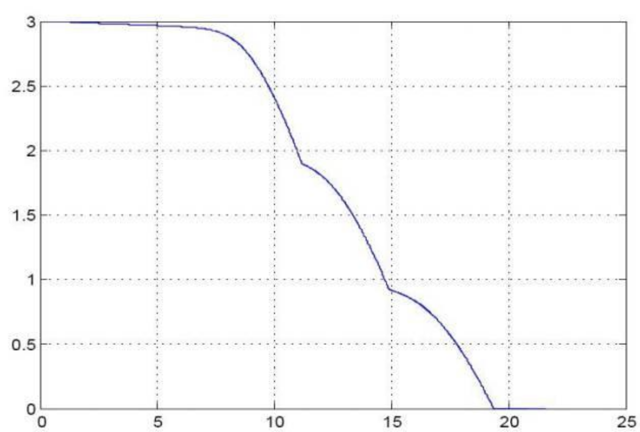

Fig.6 I-V characteristic of PV array under partial shading condition

7. CONCLUSION

Under the partial shading conditions and rapidly varying irradiance conditions almost all the conventional MPPT methods will fail to track the real maximum power point. So in order to overcome this situation, a conventional P&O based algorithm is modified for tracking global MPP. The algorithm is tested for standalone PV system using boost converter as MPP tracker. The simulation result shows the effectiveness of an algorithm in tracking Maximum power point under uniform insolation as well as partial shading conditions.

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In this paper, a simple technique of maximum power generation systems based on partial to realize a simple control system to track the real maximum power point even under non-uniform or for rapidly changing insulation conditions. The proposed technique in the first stage implements a survey for the I-V characteristic of the PV arrays to detect an approximated MPP.

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