MAXIMUM POWER POINT TRACKING IN PHOTOVOLTAIC SYSTEM OPERATING UNDER PARTIAL SHADING CONDITIONS

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Abstract -- The characteristics of a solar panel are highly non-linear that shows single point on power-voltage (P-V) curve corresponding to maximum power which varies with solar radiation. As per maximum power transfer theorem, the maximum power is transferred by the solar panel when the load resistance matches the output resistance of the panel. A DC-DC converter is used for Maximum Power Point Tracking (MPPT) that matches the impedance of the load with the panel by varying the duty cycle using an algorithm. When the solar panel is partially shaded, P-V characteristics display the global peak and local peaks that changes with the change in shadow. Conventional MPPT techniques are unable to track the global peak. In this research work an algorithm is developed that can track the global peak for PV system operating under uniform insolation as well as partial shading conditions using boost converter. The algorithm is based on Perturb and Observe technique. The simulation result shows robust tracking performance of an algorithm under different partial shading conditions.

Index Terms—Photovoltaic System, partial shading, Maximum Power Point Tracking, global peak.

I. INTRODUCTION

One of the major concerns which exist in the power sector is day-to-day increasing power demand but there is unavailability of the resources to meet the demand of the power using conventional energy resources. Demand increases for the renewable energy sources to be utilized along with the conventional systems to meet the demand of the energy. Renewable energy sources like wind energy and solar energy are the major energy sources that are being utilized in this regard. The continuous use of the fossil fuel causes the fuel deposit to be reduced and affects drastically the environment resulting into depleting the biosphere and adds to the global warming [1].

Solar energy is abundantly available which makes it possible to harvest it and utilize it in a proper way. It can be a standalone unit or can be a grid connected unit depending on the availability. Thus it can be used for powering the rural areas where the availability of grids is very low.

In order to tackle the present crisis of energy it is necessary to develop an efficient manner in which the power has to be extracted from the incoming solar radiation. The power conversion technique has been reduced in size in the past few years. The constant increase in the development of the solar cells manufacturing technologies would surely utilize these technologies on a wider basis than what exactly the scenario is at present. The use of the newest power control mechanism which is called the Maximum Power Point Tracking (MPPT) algorithms has led to the increase in the overall efficiency of the operation of the solar modules which results in the field of utilization of renewable sources of energy.

As PV panels are costly, its effective utilization is necessary. It has been observed that the characteristics of PV array are highly nonlinear that gives single point which corresponds to maximum power during uniform solar insolation and different methods like Perturb and Observe (P&O), incremental conductance, open circuit voltage, short circuit current, ripple based, fuzzy based etc. are used to obtain the maximum power for the PV system operating under uniform insolation conditions. Under non-uniform insolation conditions, the power-voltage characteristics of PV array show multiple peaks amongst which only one point is global peak. Therefore it is essential to operate PV array at global peak otherwise considerable amount of power loss occur. Hence, the need is to develop an MPPT algorithm based on the study of existing methods that can be able to track global peak by means of converter under any shadowing condition.

II. PV ARRAY MODELING AND CHARACTERISTICS

A single diode PV cell which is used in the simulation study is shown in the Fig 1. It consists of a diode in parallel with a current source and shunt resistance which is neglected as its value is high [2]. There is a desirable change in PV current and power if the values of parameters like temperature and insolation varies.

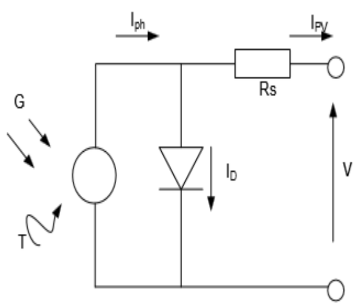

Fig 1 PV cell model

From the electrical equivalent circuit model of PV cell shown in Figure 1, the PV output current is given by,

$$I_{PV} = I_{ph} - I_D - I_{sh} \qquad (1)$$

where,

$$I_D = I_0(e^{\frac{(q(V_{PV}+I_{PV}R_S)}{\eta kT}} - 1) \qquad (2)$$

and

$$I_{PV} = \frac{(V_{PV} + I_{PV}R_S)}{R_{sh}} \qquad (3)$$

where, q = electronic charge = 1.6 x10^{-19} C

η = diode ideality factor

k = Boltzmann constant = 1.38 x 10^{-23} $m^2kgs^{-2}K^{-1}$

T= Temperature in kelvin

Iph= Photocurrent

Io= diode reverse saturation current

Ipv= PV current

Vpv= PV voltage

The PV array is formed by connecting N_s series connected

modules known as string and N_p such strings are connected in parallel. Thus the PV array output current is given by Eq. 4.

$$I_{PV} = N_p(I_{ph} - I_0(e^{\frac{(V_{PV}+I_{PV}(\frac{N_S}{N_p})R_S)}{\eta kTN_S}} - 1)) \qquad (4)$$

The MATLAB model of PV array is developed using Eq. 1 to Eq. 4. The P-V and I-V characteristics of PV array under different insolation and temperature are obtained using MATLAB simulation.

Maximum power point tracking algorithm:

A solar panel can convert only 30-40% of the solar irradiation into electrical energy. Therefore it is required to operate PV array at MPP to improve the overall efficiency. According to Maximum power transfer theorem, the maximum power output is obtained when the Thevenin's impedance of the circuit match with the load impedance. Thus, the problem of tracking the maximum power point reduces to impedance matching problem. Between PV array and Load, a boost converter is connected whose duty ratio is controlled for maximum power transfer to the load from PV array. When the duty cycle is changed for the boost converter a match for the source with load impedance is done. The converter also boosts the voltage as per duty ratio.

There are different techniques used to track the maximum power point. Few of the most popular techniques are [3]:

1. Perturb and observe (hill climbing method)
2. Incremental conductance method
3. Fractional open-circuit voltage
4. Fractional short-circuit current
5. Fuzzy logic
6. Neural networks

From the comparison of different MPPT techniques for the uniform insolation conditions and as per the convenience of the algorithm Perturb & Observe technique is used here.

III. MPPT UNDER PARTIAL SHADING CONDITION

Factors such as aging, dust and partial shading results in mismatching and in non-uniform operation conditions. Partial shading occur when some cells within module are shaded by buildings, birds, passing clouds etc. or may be some other objects as illustrated in Fig. 2. As the short circuit current of PV cell is proportional to insolation level, the partial shading results in reduction of photocurrent for the shaded PV cells while unshaded cells operate at higher photocurrent.

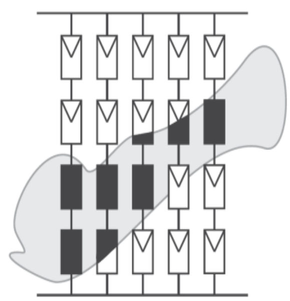

Fig 2 PV modules under the partial shading condition

The I-V and P-V characteristics are shown in Fig. 3, Fig. 4 and Fig. 5. for different three shading patterns with the peak point located in the different voltage regions . It can be seen that under partial shading conditions, the I-V characteristics will show multiple steps and the P-V characteristics will show the multiple peaks amongst which only one of the point is the global peak point. Also, the location of this global peak point on the P-V curve is random and will depend on the shadowing conditions. But it can clearly be observed that the local or global peak points will lie nearby the voltage which is in the multiple of 75-80% of the PV module's operating open circuit voltage [4],[5].

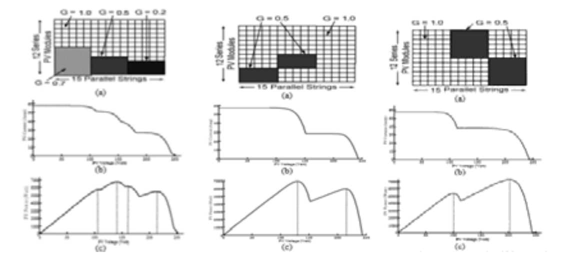

Fig 3a) shading pattern1 Fig 4a) shading pattern-2Fig 5 a) shading pattern-3
b) I-V characteristics b) I-V characteristics b) I-V characteristics
c) P-V characteristics c) P-V characteristics c) P-V characteristics

Conventional MPPT algorithms may not be able to distinguish between the local and global maximum.

The Maximum Power Point Tracking Techniques for shaded photovoltaic arrays are:

1. Power Slope Curve
2. Load Line Maximum Power Point Tracking
3. Power Incremental Technique
4. Fibonacci Search
5. Artificial Neural Network

Perturb and observe based global peak tracking algorithm:

The global peak power point tracking algorithm will scan the entire P-V curve at a particular predefined voltage steps that will be in the multiple of 75% of the module's open circuit voltage in order to obtain the approximate global peak power point. The scanning can be performed at a particular time interval. Then the PV array is operated at a voltage which is corresponding to the approximate global peak point and then the conventional Perturb and Observe algorithm is used to track the real MPP of the operating system [5].

IV. CONFIGURATION OF GLOBAL PEAK POWER POINT TRACKER

The PV array is made up of number of PV modules which are connected in series known as string and number of such strings are connected in parallel to obtain the desired voltage and current. As shown in Fig 6, to protect the PV modules from the problem of hot spot, a bypass diode is connected in parallel with each module and to protect the PV module from the effect of potential difference between the PV strings, the blocking diode is connected in series with each string [5]. The PV array configuration which is used for the simulation study is shown in Fig 6.The modules are connected as three of the modules are connected in series and these three series connected modules are connected in parallel with another set of three series connected modules as shown in the configuration.

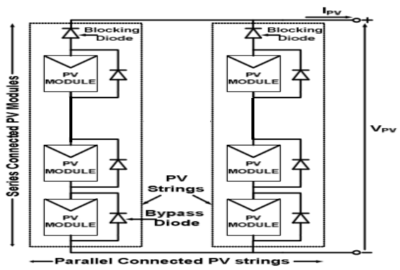

Fig 6 PV array configuration

The block diagram for the implementation of the Maximum Power Point Tracking system which consists of the PV panel, a DC-DC converter, MPPT control block and load is shown in Fig 7.

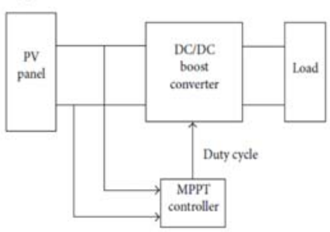

Fig. 7 Block diagram of the MPPT system

The flowchart for the global peak point tracking algorithm which is used in the MPPT controller is shown in Fig 8.

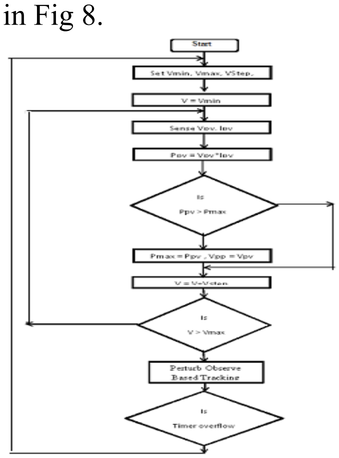

Fig 8 Flowchart of the perturb & observe global peak power point tracking algorithm [5]

It is observed from the I-V and P-V characteristics in all the three different cases, the local maximum power is obtained approximately at 75% of the module's open circuit voltage. According to the algorithm which is described in Fig. 8, the step of the voltage Vstep is chosen in such a way that the PV voltage varies in step of 75% of the module's open circuit voltage during the scanning period. The Vmin is chosen corresponding to 75% of the module's open circuit voltage and Vmax is chosen corresponding to 75% of the array open circuit voltage. In the beginning Pmax is initialized to zero. During each scanning step, after sensing the PV array voltage V_{PV} and I_{PV}, the PV power is determined. The calculated PV power is then compared with the stored maximum power Pmax and if it is higher than the stored value, Pmax is updated with the new maximum power and the corresponding Vmax is also updated. This process is repeated until the entire P-V curve is scanned and the approximate global peak point is thus obtained. The algorithm then sets the duty ratio of the boost converter corresponding to the searched approximate peak point and then the conventional P & O tracks the real global peak power point and will operate the PV array at the global peak point. Again after the specified time interval, the scanning and tracking is repeated that will keep the PV array operating at real MPP under the partial shadowing as well rapidly changing environmental conditions.

V. SIMULATION RESULTS

The modeling of PV system is done in MATLAB/Simulink. The block diagram is shown in Fig 9.

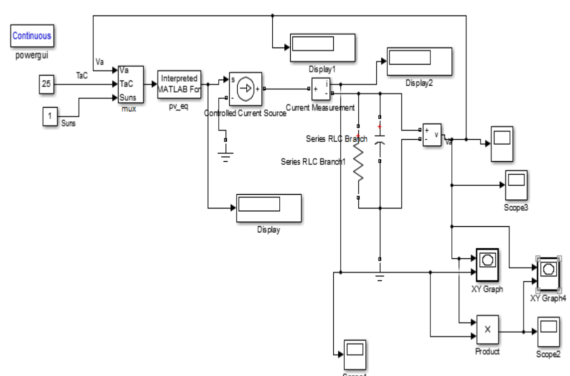

Fig 9 PV system model

The P-V and I-V characteristics obtained from the PV system model shown in Fig. 9 are shown in Fig. 10 and Fig. 11 respectively.

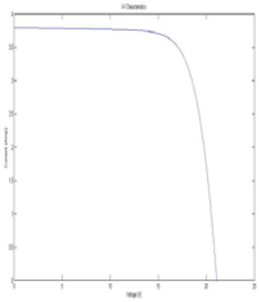

Fig 10 I-V characteristics for uniform condition

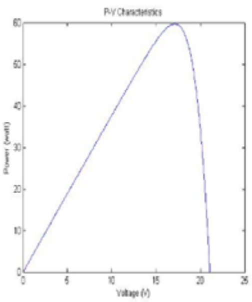

Fig 11 P-V characteristics for uniform condition

The Matlab/Simulink model for obtaining the maximum power point under the uniform insolation conditions is implemented as shown in Fig 12.

It consists of the PV module, DC-DC converter as Boost converter and perturb and observe algorithm is used to obtain the maximum power with the help of the boost converter by the impedance matching phenomenon.

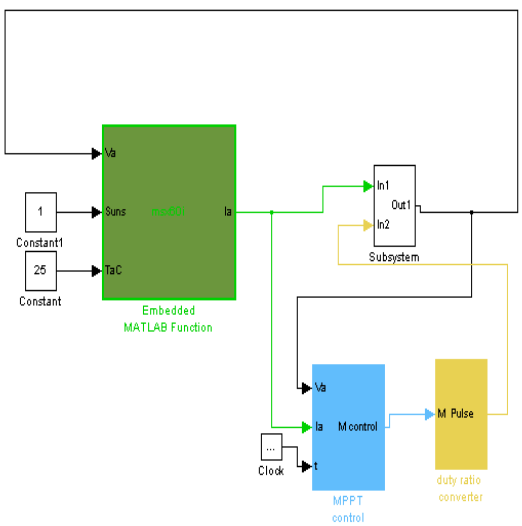

Fig 12 MPPT model for uniform insolation conditions

The characteristics for the Ipv, Vpv and Ppv for the uniform insolation conditions are obtained from the Fig 12 are shown in Fig. 13. As shown in the figure, the maximum power point is achieved at nearer to 60W and then it remains at the maximum power point for the entire simulation interval. So the MPPT is said to have achieved for the uniform insolation conditions.

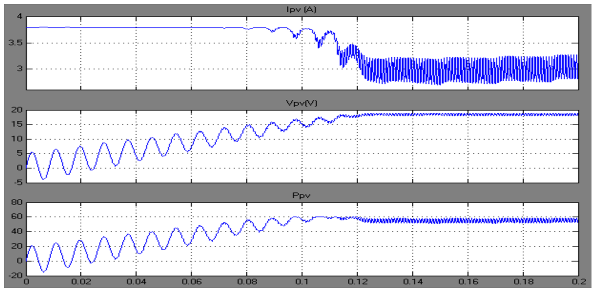

Fig 13 Ipv, Vpv and Ppv characteristics for the PV module under uniform insolation conditions.

In Fig 14, it can be seen that the Vo is obtained 64.73V for the Vin of 18.76V which is acceptable according to the relation Vo/Vin = 1/1-D. The configuration of the DC-DC boost converter for R= 100Ω, Cpv= 1000µF, L= 2mH and Cboost = 2000 µF is shown in Fig 14.

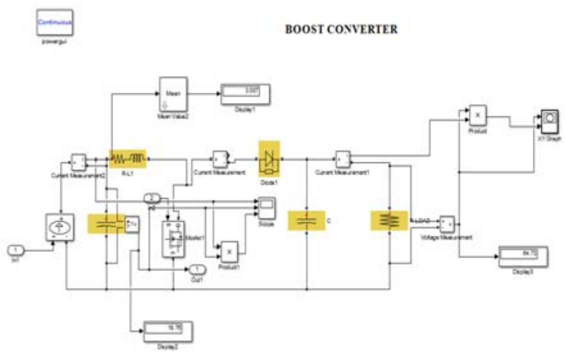

Fig 14 Boost Converter for maximum power point operation

The MATLAB/Simulink model for the maximum power point under the partial shading conditions using the perturb and observe global peak power algorithm is shown in Fig 15.

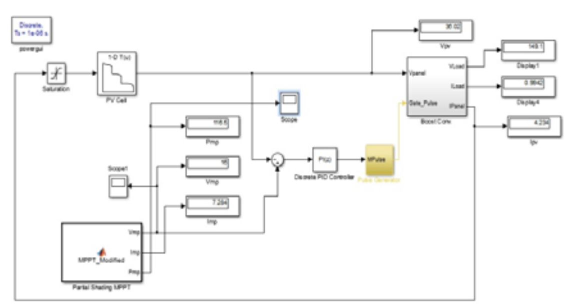

Fig 15 MPPT model for operation under partial shading conditions

The characteristics for the voltage v/s time and power v/s time for the uniform insolation conditions are obtained from the Fig 15 are shown in Fig. 16 and Fig.17. As shown in the figure, the maximum power point is achieved at nearer to 154 W and then it remains at the maximum power point for the entire simulation interval. So the MPPT is said to have achieved for the varying insolation conditions.

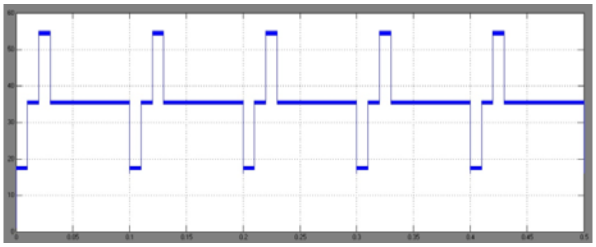

Fig 16 Voltage v/s Time characteristics for the PV module under varying insolation conditions

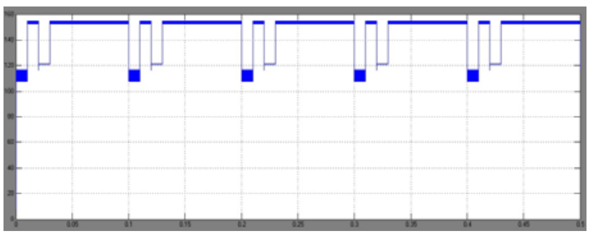

Fig 17 Power v/s Time characteristics for the PV module under varying insolation conditions

VI. 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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