Comparative Study of Perturb and Observe Method and Incremental Conductance Method under Atmospheric Perturbations

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Abstract – 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. This paper presents MATLAB simulations done with Perturb & Observe (P&O) maximum power point tracking (MPPT) method and incremental conductance (IncCond) MPPT method used in solar array power systems. Performance of MPPT methods 'Perturb and Observe' and 'Incremental Conductance' is observed for rapidly changing temperature, rapidly changing solar radiation, constant temperature and constant solar radiation. The simulation results are presented and the results are compared for both MPPT methods.

Index Terms – Maximum power point tracking, Perturb and Observe method, Incremental conductance method.

1. INTRODUCTION

Renewable resources, are offering many challenging scopes for the researchers since past few decades by showing their never ending power generation capability. Non-conventional sources based power generation ranges from a few watts to millions of watts. When compared to other renewable sources, solar offers the best with its wide range of availability, maximum utilisation capability, ecofriendliness and less operational and maintenance cost. Considering all, "Photovoltaic Generation" is playing an important role due to its sustainable development. The biggest challenge faced by the researchers in PV generation is its low efficiency due to the nonlinearity in output characteristics with varying insolation levels. Even though the theoretical efficiency is about 28% practically it will meet only about 15% [1-2]. So for effective utilisation of PV based generation, it is necessary to improve the efficiency of the photo voltaic system by some cost effective techniques like "Maximum Power Point Tracking (MPPT)" algorithm. Recently many MPPT algorithms and control schemes of PV generation system have been proposed. In this paper, output power obtained from two commonly used MPPT techniques, Incremental Conductance and P&O algorithm are compared at constant temperature and insolation level as well as at varying temperatures and at varying insolation levels.

1.1 Block Diagram of PV System with MPPT

The principle of maximum power point tracking (MPPT) is to place a convertor between the load and the PV array, as shown in Fig. 1, to regulate the array output voltage (or current) so that the maximum available power is extracted. Usually, when a PV module is directly connected to a load, the operating point is rarely at the maximum power point or MPP. A power converter is necessary to adjust the energy flow from the PV array to the load. In the method described in, the power converter is controlled using the PV array output power.

Voltage and current sensing allow measuring the power. If the value of power is available can be decided if go up or down on the power curve. The PV array is an unregulated dc power source, which has to be properly conditioned in order to interface it to the grid. The dc/dc converter is present at the PV array output for MPPT purposes, i.e. for extracting the maximum available power for a given insolation level. The step-down dc/dc converter (buck converter) is used as a dc transformer which can match the PV array optimum load by changing its switching duty ratio (D). In general, the operation of an ideal buck converter is described by (1).

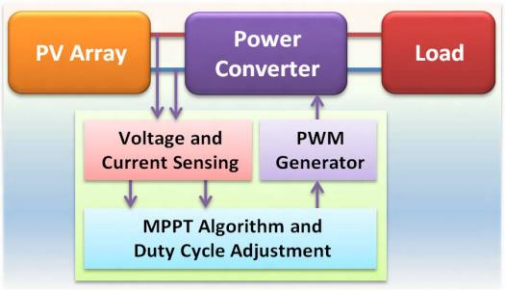

Figure 1. Block diagram of a PV array connected to the load

$$V_{out}/V_{in} = I_{in}/I_{out} = D \quad \ldots(1)$$

Where Vin and Iin are the voltage and current at the PV array side (i.e. the input of the buck converter), and Vout and Iout are the voltage and current at the load side (i.e. the output of the

buck converter). Multiple well-known direct control algorithms are used to perform the maximum power point tracking (MPPT).

2. MPPT METHODS

There are a large number of algorithms that are able to track MPPs. Some of them are simple, such as those based on voltage and current feedback, and some are more complicated, such as perturbation and observation (P&O) or the incremental conductance (InCond) method. They also vary in complexity, sensor requirement, speed of convergence, cost, range of operation, popularity, ability to detect multiple local maxima, and their applications. Algorithms of Perturb and Observe method and Incremental Conductance method are studies below:

2.1 Perturb and Observe method of MPPT algorithm

The P&O algorithm operate by periodically perturbing, i.e., incrementing or decrementing the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the PV array operating voltage changed and power increased, the control system moves the PV array operating point in the same direction. Otherwise the operating point is moved in the opposite direction. This method is simple, easy to implement and economical, but at the same time it has disadvantages since every time it has to disturb array terminal voltage at maximum point, which results in more oscillations and also if irradiation level is varying continuously it fails to predict maximum power point. In the P&O method of MPPT algorithm shown in Fig.2, voltage and currents are taken as input and finally adjust the duty cycle based on it.

2.2 Incremental Conductance method of MPPT Algorithm

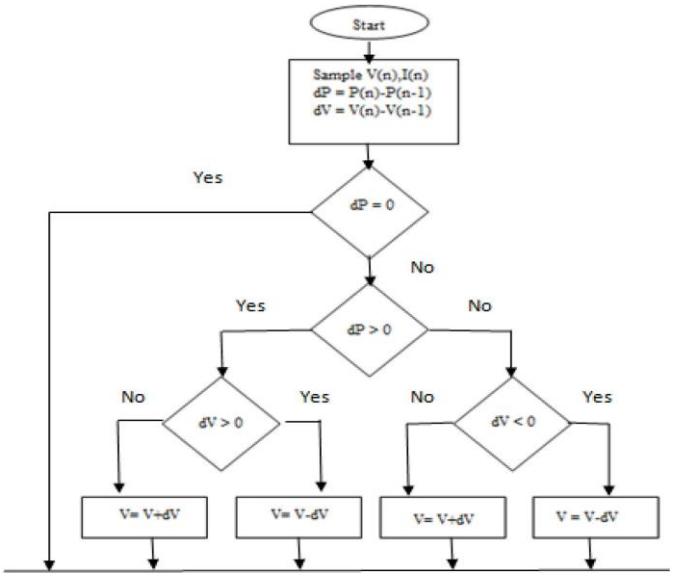

Figure 2. Flow Chart of Perturb and Observe MPPT algorithm

Incremental Conductance method predicts the MPP by judging whether PV system is proceeding to the right or left of MPP. Based on this, Incremental Conductance algorithm guides the system towards MPP. The step change can be done by incrementing the conductance value dI/dV. The system moves from initial to next step if there is an increment in conductance value otherwise it will remain in the same position. If $\Delta P/\Delta V<0$, then system is moving to the right of MPP, if it $\Delta P/\Delta V >0$, then it is to the left of MPP else it is at MPP. In this way MPP is predicted in this algorithm. Fig.3. represents Incremental Conductance algorithm. The advantage of this algorithm is its robustness to weather changes and its disadvantages are its complexity.

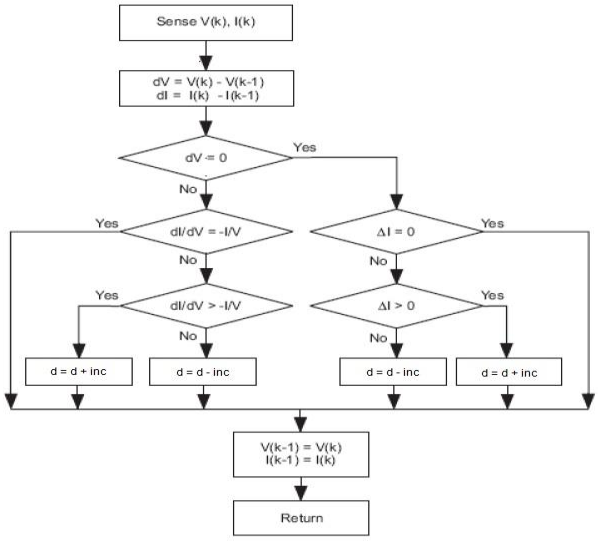

Figure 3. Flow Chart of Incremental Conductance MPPT algorithm

3. SIMULATION

MATLAB Simualtion model is of Photovoltaic system with MPPT controller is shown in Fig. 4. As explained earlier, two MPPT techniques will be taken into consideration and their results at rapid temperature perturbations and rapid insolation level perturbations will be demonstrated on MATLAB Simulation. Also, output power at constant temperature and constant insolation level are also shown below. Separate MATLAB models are designed for both algorithms i.e. P&O and Incremental Conductance.

3.1 Rapid Temperature Perturbations:

Rapid changes in temperature are given as input to PV array model. This condition is given to the simulation model of P & O method as well as InCond method. Fig. 5 shows the temperature variations taken into account to study the PV array output obtained for P & O method and InCond method. Total ten temperature samples i.e 20°C, 25°C, 30°C, 40°C, 45°C, 46°C, 43°C, 42°C, 38°C and 32°C are taken as input samples

for equal interval of time into simulation. Solar radiation is kept constant at 700W/m2. The PV array output power for Perturb and Observe (P & O) method and Incremental Conductance (InCond) method are analysed. Fig. 6 shows the PV array output power using P&O method at varying temperature. Fig. 7 shows the PV array output power using InCond method at varying temperature. From fig. 6 and 7 it can be clearly seen that, the PV array output obtained from P&O method is around 350 W while from InCond method it is around 700 W for rapidly perturbing temperatures. Also, PV array output power from InCond method has comparatively less oscillations than P & O method.

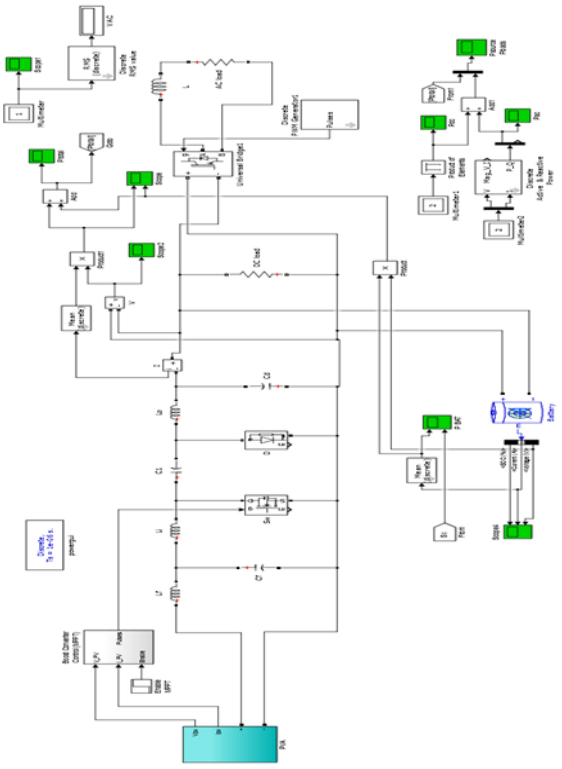

Figure 4. MATLAB Simulation Model

3.2 Rapid Solar Radiation Perturbations:

Rapid changes in solar radiation are given as input to PV array model. This condition is given to the simulation model of P & O method as well as InCond method. Fig. 8 shows the solar radiation variations taken into account to study the PV array output obtained for P & O method and InCond method. Total ten solar radiation samples i.e 700W/m2,900 W/m2, 1000W/m2, 1200W/m2, 1100W/m2, 950W/m2, 850W/m2, 1300W/m2, 1050W/m2 and 800 W/m2 are taken as input samples for equal interval of time into simulation. Temperature is kept constant at 30°C. The PV array output power for Perturb and Observe (P & O) method and Incremental Conductance (InCond) method are analysed. Fig. 9 shows the PV array output power using P&O method at varying solar radiation. Fig. 10 shows the PV array output power using InCond method at varying solar radiation.

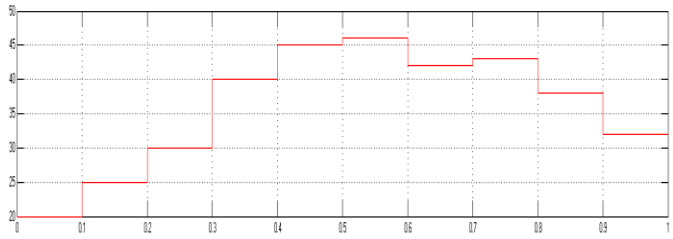

Figure 5. Temperature range of 10 samples

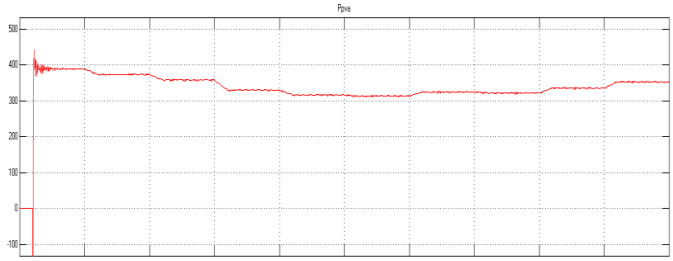

Figure 6. PV array output power by P & O method at varying temperatures

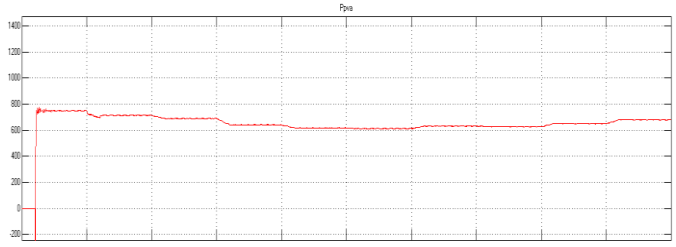

Figure 7. PV array output power by InCond method at varying temperatures

From fig. 9 and 10 it can be clearly seen that, the PV array output obtained from P&O method is oscillating in between 2000W and 4000W. While, the PV array output obtained from InCond method is also oscillating in between 2000W and 4000W for rapidly perturbing temperatures. But, the PV array output is definitely more for Incond method than P & O method. Also, PV array output power from InCond method has comparatively less oscillations than P & O method.

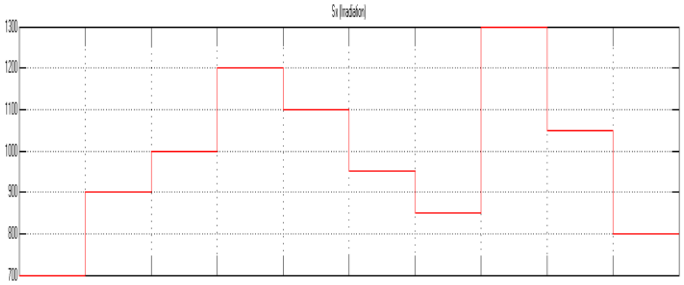

Figure 8. Temperature range of 10 samples

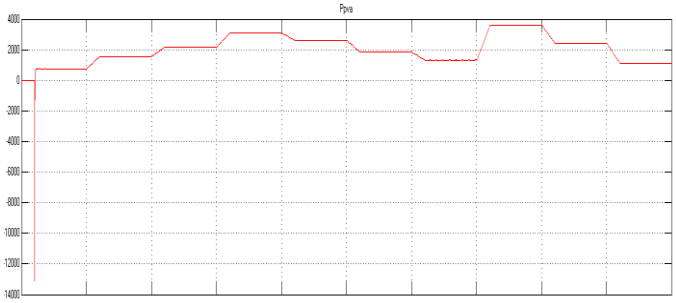

Figure 9. PV array output power by P & O method at varying solar radiation

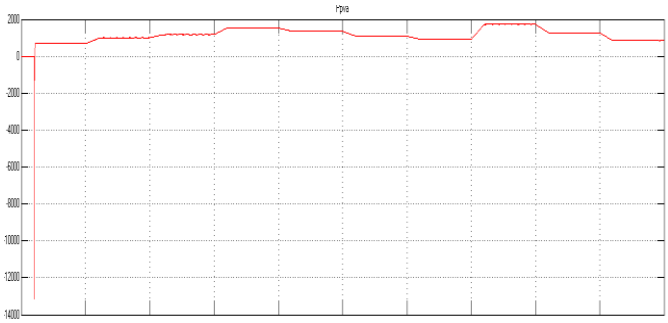

Figure 10. PV array output power by InCond method at varying solar radiation

3.3 Constant Temperature and Solar Radiation:

After studied rapid perturbations in temperature and solar radiation, now P&O method and InCond method are compared for constant temperature and solar radiation condition. Three temperature samples i.e. 25°C, 30°C and 35°C are given keeping solar radiation constant at 700 W/m2. PV array output for P&O method and InCond method is measured from the waveform obtained after running the simulation and results are presented in tabular form. Table 1 shows the results obtained. Three solar radiation samples i.e. 700 W/m2, 1100 W/m2 and 1500W/m2 are given keeping temperature constant at 30°C. PV array output for P&O method and InCond method is measured from the waveform obtained after running the simulation and results are presented in tabular form. Table 2 shows the results obtained.

PV Array output in Watts			
Solar radiation	700 W/m2		
Temperature	25°C	30°C	35°C
P & O method	803 W	754 W	707 W
InCond method	724 W	700 W	674 W

Table 1 Comparison of PV array output power for constant solar radiation

PV Array output in Watts			
Temperature	30°C		
Solar radiation	700W/m2	1300W/m2	1500W/m2
P & O method	803 W	1930 W	3050 W
InCond method	724 W	1806 W	2230 W

Table 2 Comparison of PV array output power for constant temperature

From, table 1 it is observed that, PV array power output from P & O method is more when solar radiation is kept constant and output is checked by keeping temperature at three temperatures but only one at a time. At every temperature, output PV array power is more for P & O method than InCond method. Similarly, from table 2 it is observed that, PV array power output from P & O method is more when temperature is kept constant and output is checked by keeping solar radiation at three values but only one at a time. At every solar radiation, output PV array power is more for P & O method than InCond method.

4. RESULTS AND DISCUSSION

Performance of MPPT methods 'Perturb and Observe' and 'Incremental Conductance' is observed for rapidly changing temperature, rapidly changing solar radiation., constant temperature and constant solar radiation . It is observed than Incremental conductance method gives better performance than Perturb and Observe method when temperature and solar radiation are changed rapidly. Less oscillations and almost constant PV array output power is obtained from InCond method compared to P&O method. But, when temperature is kept constant and solar radiation is also kept constant, PV array gives more output power from P&O algorithm than InCond algorithm. So, from the results obtained, it can be concluded that, P&O method is better where ambient temperature and incident solar radiation are almost constant throughout the day. Another advantage of P & O method is that, it is simpler in implementation than InCond method. But, area where ambient temperature and incident solar radiation keep on changing, at such area, incremental conductance should be preferred as PV array output power is more than P&O method. Disadvantage of InCond method is that, it requires complex circuitry and algorithm than P &O method.

5. CONCLUSION

The PV simulation system used in this paper is set up under Matlab/Simulink environment. Two MPPT methods: perturb & observe method and incremental conductance method are considered as these methods are widely used algorithms for solar power generation. The photovoltaic array output power for each MPPT algorithm are simulated under rapidly varying temperature conditions as well as rapidly varying solar radiations. Simulation for both MPPT methods is also studied for constant temperature and constant solar radiation. The

results obtained from these two methods are observed and analyzed. Perturb and Observe method is simple in implementation than incremental conductance. P & O method give a fair performance when temperature and solar radiation are kept constant. But, at rapidly varying temperature and solar radiation, incremental conductance gives more as well as stable PV array output power than P & O method. The results obtained show that the power produced by a PV array is an attractive option for homes who desire cheap electricity in long run.

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