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Voltage Distinguished Perturb and Observe Technique to Tackle Fast Changing Irradiation and Partial Shading Conditions

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ABSTRACT

The characteristic exhibited by a Photovoltaic (PV) module normally is of non-linear in nature and this characteristic is further complicated by change in the level of irradiation and temperature. These complications gets worsen further due to partial shading of the PV module wherein multiple peaks of maximum power points (MPP) occur. In order to extract maximum possible power from the PV module many maximum power point tracking techniques (MPPT) were suggested and perturb and observe technique of MPPT is more popular. Though this technique is good in performance it fails to track the MPP under partial shaded conditions. Hence in order to obviate such a lacuna in the P&O technique effort has been put to modify the technique such that it can track the global MPP under partial shading conditions.

Introduction

Due to the nonlinear characteristics exhibited by the photovoltaic modules extraction of maximum possible power is a difficult task and hence method were devised to extract maximum power from them, these methods are called as Maximum Power Point Tarcking (MPPT). The technique of maximum power point tracking for photovoltaic modules is one among the techniques researched in a great extent with different approaches. Ishaq and Salam and Laurent have reported that the maximum power point tracking of photovoltaic modules vary in complexity, types of sensors required, convergence speed, cost and in other respects also. Other researchers have categorised the different techniques of maximum power point tracking techniquesin different ways. Of them the most appealing way of characterizing MPPT techniques is by two different methods as indirect and direct methods.Whereas Masoumet al (2007) have categorized the MPPT techniques proposed so far into four main branches as Load matching, Computational, Perturb and Observation (P&O) and intelligent techniques.

Normally uniformly irradiated photovoltaic modules exhibits nonlinear current to voltage characteristic curves in such a way that the power to voltage characteristic curve exhibited by photovoltaic module will offer only one maximum power point. Due to the dependence over irradiation level and surface temperature of the photovoltaic module the characteristic curve exhibited by them will vary from time to time and hence extracting optimal power from the photovoltaicmodule is very difficult. Taking into account these considerations different maximum power point tracking techniques are evolved. So far almost many methods are incapable of tracking the maximum power point under non uniform irradiated conditions. Hence new maximum power point tracking techniques are developed such that the maximum power that can be delivered by a photovoltaic module under a particular environmental condition will be extracted from them. The case will be more complicated if a part or more portion ofthe array does not receive uniform insolation, as in partially cloudy conditions due to passing by clouds, neighbouring structures either artificial or natural, etc., resultingin multiple peaks. The presence of multiple peaks due to the inclusion of bypass diodes, to protect the shaded cells or modules, reduces theeffectiveness of the existing MPPT due to their inabilityto discriminate between the local and global maxima.

Especially the popular perturb and observe technique which performs excellently during uniform irradiation levels get confused in the event of fast changing irradiation conditions due to its incapability to discern the increase or decrease in power output from the PV module is due to change in the level of irradiation or change in voltage increment. This problem becomes culminated under non uniform irradiation over the PV array due to multiple peaks. In this paper a method is suggested to circumvent the problem in perturb and observe technique at the time of non-uniform irradiation. The method proposed has good tracking efficiency and have the capacity to track and settle in the global maximum power point. The technique proposed is evaluated using computer simulation using a popular software PSIM.

I-V CHARACTERISTICS OF THE PV MODULE

The characteristics of a PV module is dictated mainly by the following chief factors such as,

i. Number of Cells connected in Series

ii. Number of Cells connected in Parallel

iii. Level of Irradiation

iv. Level of atmospheric temperature

v. Characteristics of the PN junctions of the cells

vi. Parasitic Resistances of the cells etc.

As many factors influence the behaviour of the PV modules, the characteristics exhibited by them is quite a complicated one. The mathematical model of a typical PV module, given by Tianet al (2012), Kim &Youn(2005), consisting of N_S number of series cells and N_P number of parallel cells can be expressed by the expression given in the Equation (1).

Assuming a constant level of solar irradiation and atmospheric temperature, the characteristic exhibited by a typical PV module having a single string is shown in Figure 1, which clearly indicates that the PV modules exhibit a complex non-linear behaviour. As a consequence it is obvious that the control of the PV modules becomes quite a laborious task.

$$I = N_p I_{ph} - N_p I_{os}\left[\exp\left(\frac{\left(V + I\left(\frac{N_s}{N_p}\right)R_s\right)}{N_s\left(\frac{nk_BT}{q}\right)}\right) - 1\right] - \frac{V + I\left(\frac{N_s}{N_p}\right)R_s}{\left(\frac{N_s}{N_p}\right)R_{sh}} \quad (1)$$

where ‘I’ is the PV module’s terminal current, ‘I_{ph}’ is the photo-generated current, ‘I_{os}’ is the reverse saturation current, ‘V’ is the PV module’s terminal voltage, ‘V_T’ is the volt equivalent to temperature, ‘N_s’ is the number of PV cells connected in series, ‘N_P’ is the number of PV cells connected in parallel, ‘R_{se}’ is the series resistance of the PV cell, ‘R_{sh}’ is the shunt resistance of the PV cell, ‘n’ is the diode ideality factor, ‘k_B’ is the Boltzmann constant and ‘T’ is the temperature of the PV cell.

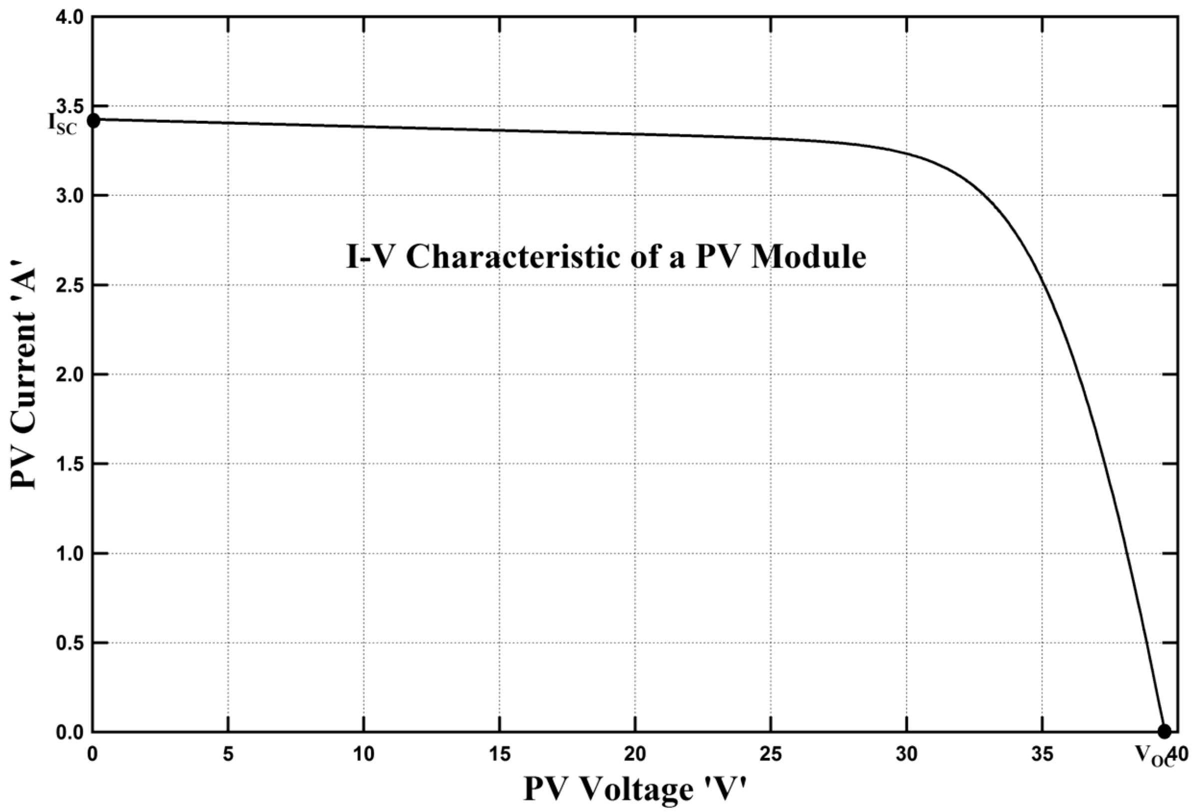

Figure 1 A typical I-V characteristic of a PV module

EFFECT OF IRRADIATION ON I-V CHARACTERISTICS

Since the photo generated current ‘I_{ph}’ in Equation (1) depends on the magnitude of the solar irradiation, the characteristic curve of the PV module will be shifted either up or down by a level proportional to the magnitude of the photo current ‘I_{ph}’ generated. Neglecting the influence of the material characteristic parameters by which the cells of the PV modules are made up of, a typical family of characteristic curve showing its behaviour, due to the variation in the level of solar irradiation, is depicted in the Figure 2. This plot put into evidence the strong dependence of PV module’s performance on the level of irradiation. It is noteworthy from the Figure 2, that the open circuit voltage of the PV module is least affected whereas the short circuit current is almost linearly dependent on the irradiation level.

P-V CHARACTERISTICS OF THE PV MODULE

The P-V Characteristic can be obtained from the mathematical model of the I-V characteristic given in Equation (1) by multiplying both sides of the equation by the terminal voltage ‘V’ of the PV module. It is also noted here that the P-V characteristic behaviour of the PV module is also influenced by the same factors as that of the I-V characteristic. The graphical representation of a typical P-V characteristic obtained through computer simulation is shown in Figure 3, which clearly illustrates that the P-V characteristic is also non-linear in nature. The plot clearly puts into evidence the presence of a maximum power point (MPP) at the location wherein the tangent to the P-V characteristic curve is horizontal.

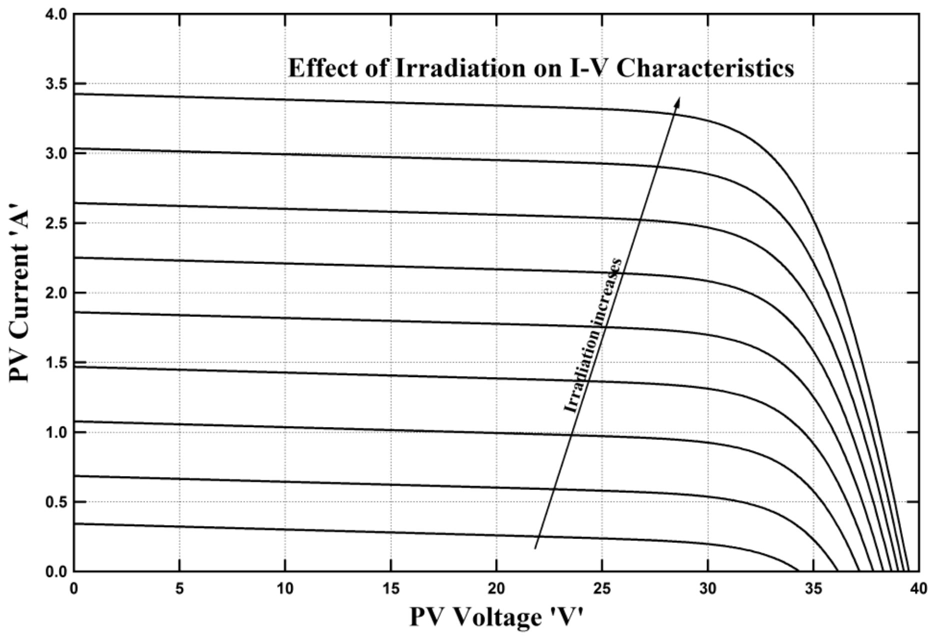

Figure 2A typical family of I-V characteristics of a PV module showing the effect of change in irradiation

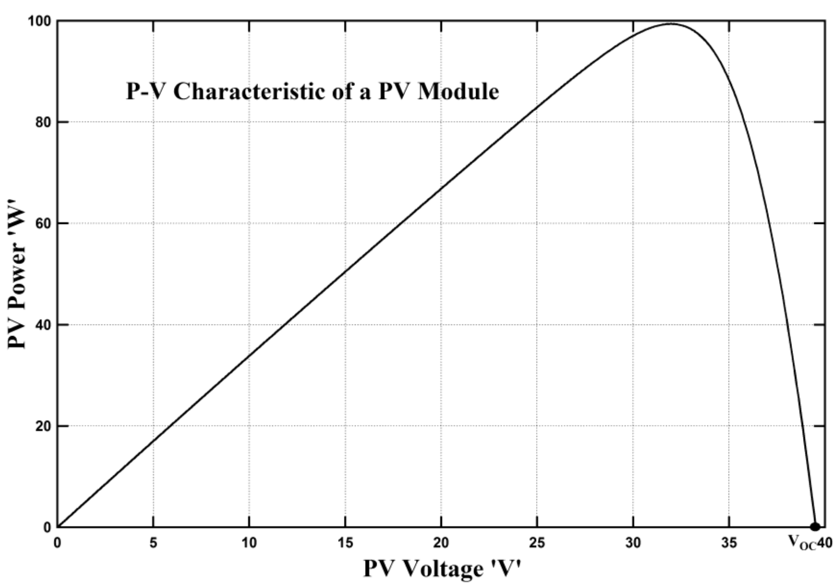

Figure 3 A typical P-V characteristic of a PV module

EFFECT OF IRRADIATION ON THE P-V CHARACTERISTICS

As the power output from the PV module depends on the level of solar irradiation, its P-V characteristic is also changing in correlation with the magnitude of the incident solar radiation. A typical family of curves obtained through computer simulation by varying the irradiation in steps is shown in Figure 4, which clearly vindicates the influence of solar irradiation on the performance of power output from the PV module.

It is also evident that the peak points at which the PV module can deliver maximum possible power are also changing along with the change in the level of irradiation. In consequence of this behaviour, it is cumbersome to extract optimal power from the PV module at all the times when a fixed load is connected directly to the PV module.

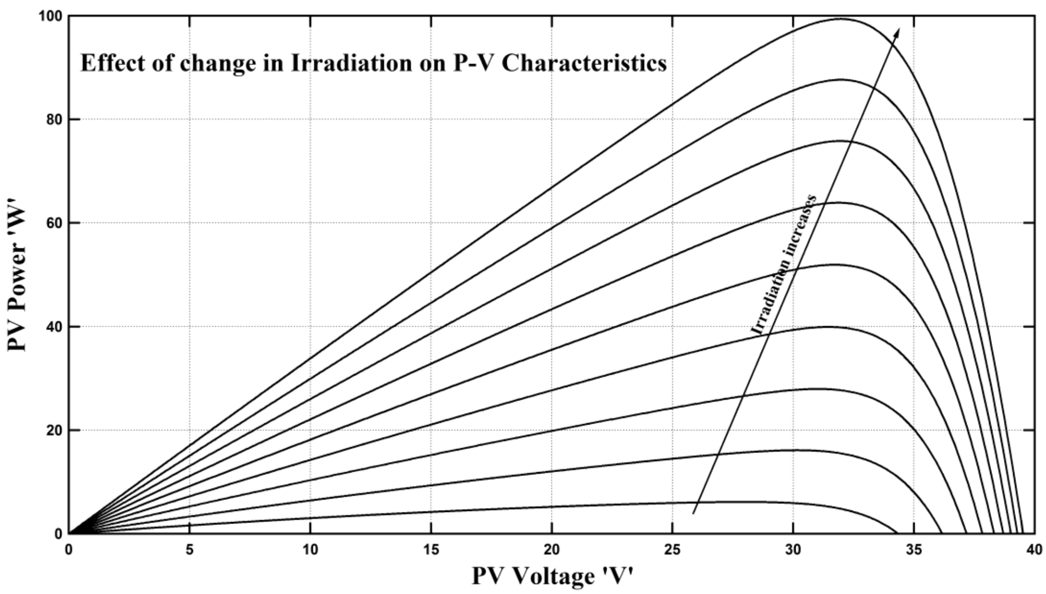

Figure 4 Effect of irradiation on the P-V characteristics

EFFECT OF NON UNIFORM IRRADIATION ON THE I-V AND P-V CHARACTERISTICS

When many cells or modules are connected either in parallel or series in order to meet out the terminal requirement of a specific application, bypass diodes are connected across them. These bypass diodes protects the shaded cell or modules from excessive voltage stress and from destruction during non-uniform irradiation on the surface of the PV cell/module. But unfortunately, due to the provision of bypass diode for the protection of PV cell/module, the characteristic behaviour exhibited by the PV cell/module becomes more complex, which produces multiple peaks in the PV characteristic and multiples steps in the IV characteristic. This characteristic behaviour of the PV module is illustrated in figure (5). The figure illustrates the PV and IV characteristic of a PV array consisting of three PV modules all connected in series shaded with different levels of magnitude.

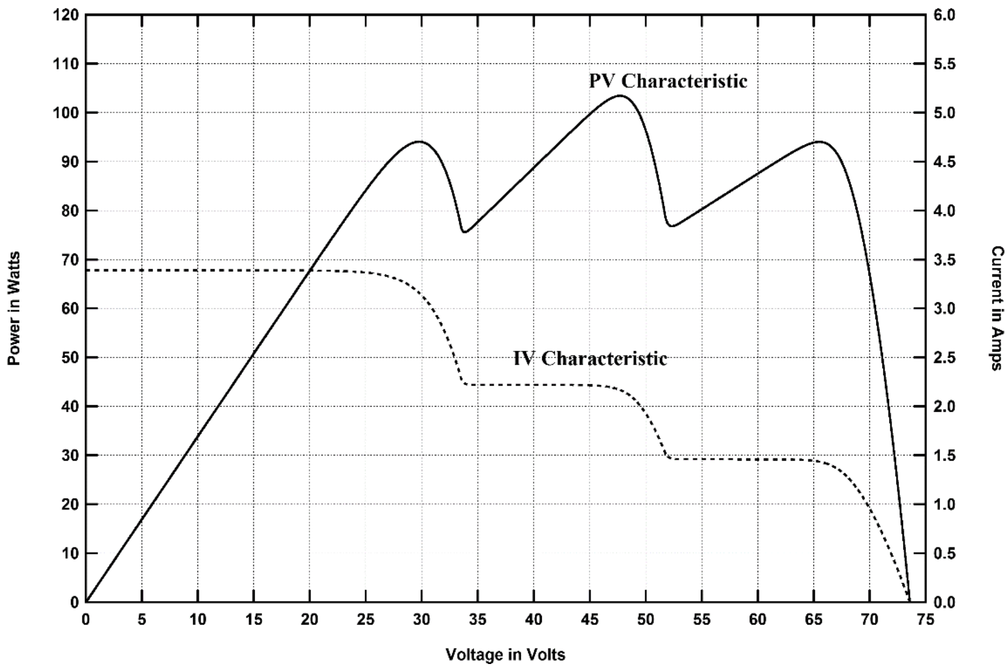

Figure 5 Effect of non-uniform irradiation on the I-V and P-V characteristics

Proposed Method of MPPT

On account of the typical deviation in characteristic behaviour of the PV generator due to non-uniform irradiation as can be seen from figure 5, it becomes quite cumbersome to track the maximum power point. The popular conventional technique perturb and observe method of MPPT cannot have the capacity to track the global MPP. Because due to its inherent nature of control technique it will settle in any one of the local maxima. The proposed method of MPPT tracking in this paper modifies the control strategy of the conventional perturb and observe technique such that it will track the global maxima under non-uniform irradiation conditions.

In the proposed technique samples of power output from the PV array at different voltages are obtained and a decision will be taken to which point the perturb and observe technique shall be applied depends on the magnitude of the power at the sampled voltage points. Then the perturb and observe technique will be launched at the point of voltage that gives the maximum power from the samples. In this way the global maximum power point is determined and tracked.

Computer Simulation

In order to verify the proposed idea of maximum power point tracking a computer simulation was carried out with the help of a software called PSIM. The simulation was executed by writing the algorithm in the C block of the software. The non-uniformity in the level of irradiation was given by giving different voltage levels as input to the PV modules. The simulation was effected at uniform temperature level. A typical steady state output from the software is shown in the figure (6).

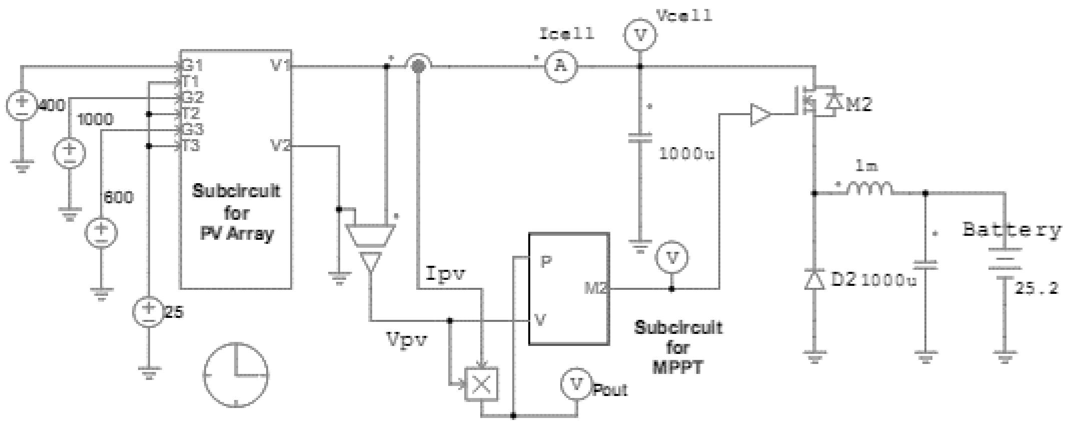

Figure 6Simulation Circuit

Results and Discussion

The steady state output from the computer simulationfor a PV array consisting of three PV modules connected in series with an irradiation of pattern with the first module having an irradiation of 400W/m^2, second module having an irradiation of 1000W/m^2 and the third module having an irradiation of 600W/m^2 is shown in figure (7).

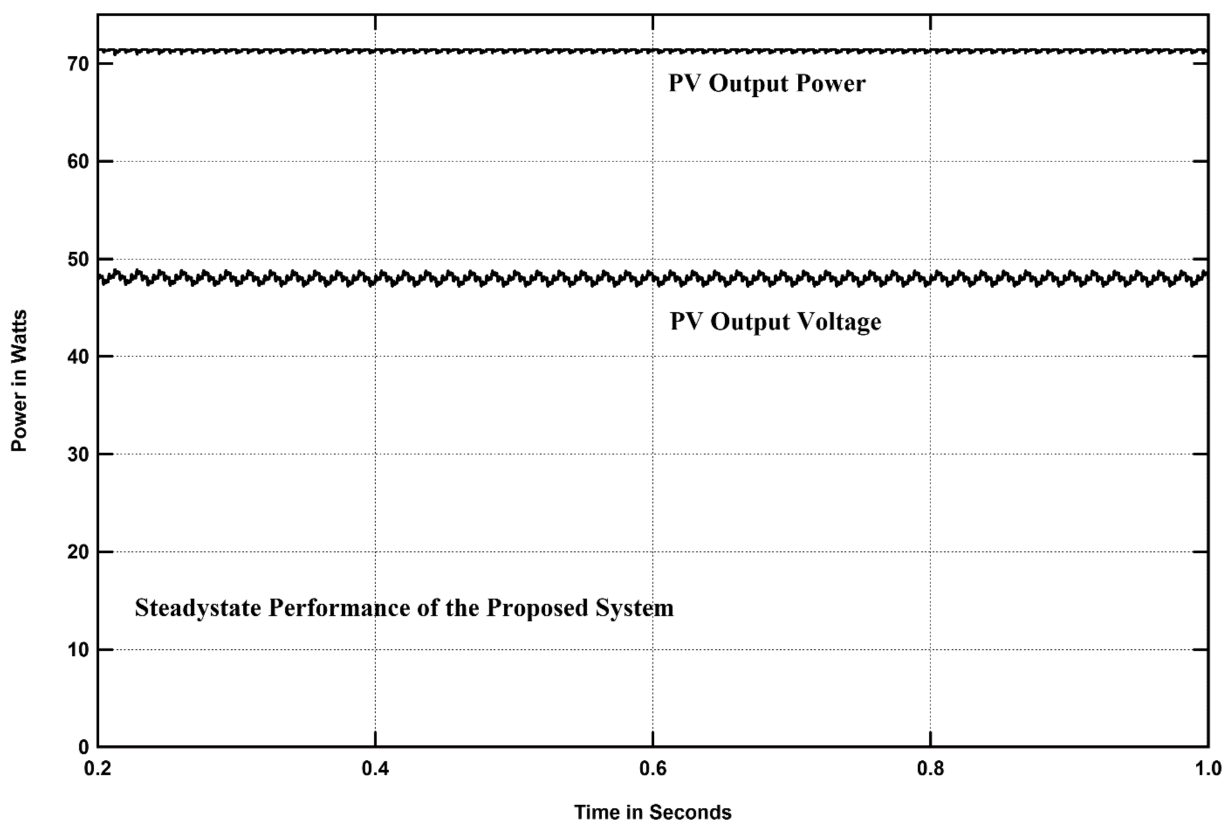

Figure 7. Steady state response of the PV array using the proposed method of MPPT

From the simulation the PV characteristic exhibits three power peaks. The first peak appears with a power of 52.57 Watts at a voltage of 14.82 volts, the second power peak appears at a voltage of 31.34 volts with a power of 68.80 watts and the third power peak appears at a voltage of 48.23 volts with a power output of 71.5 watts. As can be seen from the figure 7, the proposed method of maximum power point tracking tracks the global peak power of 71.49 watts at an operating voltage of 47.99 volts. From this it is clear that the proposed method of maximum power point tracking offers an excellent tracking, which envisages a good scope of field applications.

Conclusion

In this paper a new method of maximum power point tracking is proposed and the proposed method was also verified with the help of computer simulation. The work clearly proved that the method of MPPT tracks the global power peak and offers an excellent efficiency. Hence the method improves the conventional perturb and observe tracking technique and can be implemented in a situation wherein the PV array is irradiated in a non-uniform manner.

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