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Improvement in Perturb and Observe Method for Maximum Power Point Tracking of PV Panel

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ABSTRACT

This paper presents a continuous maximum power point tracking algorithm to get better the effectiveness of the photovoltaic panel by capturing the maximum output power from it and ensure optimum power availability to the load. As the incident solar radiation and the temperature of the panel changes continuously, in such an unpredictable parameters changing situation, the decision of locating the maximum power point is not always tedious but also a wearisome job. Up till now several MPPT techniques have been developed in different ways to resolve the problem. In these the most commonly used techniques are Perturb & Observe method, Variable Inductor method, Incremental Conductance method, and Parasitic Capacitance method for a large Photovoltaic array. In Perturb and observe method, we can improve the efficiency of PV panel through variation in duty cycle using a special control mechanism. Also we present some simulation results of PV panel for a specific location with all parameters known. Finally we will show that the efficiency of Perturb and Observe method can be increased significantly using our proposed technique.

KEYWORDS: Photovoltaic (PV) panel, Maximum power point tracking (MPPT), Perturb and Observe (P & O) method, incident solar radiation (INSOLATION), DC-DC converter

I. INTRODUCTION

A day will soon dawn when earth will be deprived of fossil fuels need of the hour is to surge their alternatives, every one of us is looking forward to some reliable energy reservoir, the sources that can prove themselves not only long-lasting but also environment friendly. What can be better than those elements that are widely distributed on this planet i.e. sun, wind, rivers and geothermal power points, etc. Among all these the solar energy is the most attractive and widely distributed. The energy from sun is being used and utilized by human beings and all other creatures since time unknown. It is an extremely clean, endurable and renewable energy source, which we can exploit in the manufacturing of a solar lightning, heating, and solar cooling appliances etc. A photovoltaic cell is an electrical piece of equipment that transforms the solar energy directly into an electrical energy. It is called an electrical device, in the since because its electrical parametric quantities e.g. voltage, current and resistance varies whenever light rays are incident on it. Operating the PV panel at the maximum power point increases its efficiency by getting the maximum available power under changing weather conditions as in [11].

The maximum power point tracking (MPPT) is fundamentally an impedance tuning issue. The basic requirement is, to change the solar panel input resistance by varying the duty cycle of a DC-DC converter to match with the load resistance. The perturb and observe (P&O) is a straightforward and less expensive technique for locating the maximum power point (MPP). However major flaw of this technique is that, at nearly constant irradiation level, the operating point fluctuates around the MPP which reduces its efficiency. The second drawback is that the P&O technique can puzzles during the periods characterized by continuously varying weather circumstances as in [1].

We can mitigate the drawbacks of perturb and observe method by means of a DC to DC converter capable of having a controlled changeable duty cycle. At the steady state during the oscillation period we increases the duty cycle (D) which reduces the value of ΔP gradually and finally it reaches zero as explained in the flow chart of Fig. 8. The point at which ΔP becomes zero is the MPP. This technique is also helpful in mitigating the second drawback i.e. during changing weather condition the algorithm will locate the MPP more quickly.

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The remaining paper is structured as follows. Basic performance parameters of photovoltaic panel are presented in Section II. In Section III, we explain the maximum power point tracking strategy (MPPT) concepts. In Section IV, our proposed strategy for achieving MPPT is discussed. Conclusions are drawn in Section V.

II. BASIC PERFORMANCE PARAMETERS OF PV PANEL

A. MODELING OF PV ARRAY:

A photovoltaic panel comprises of a several cells connected in parallel and series combination. Parallel combination of PV cells is responsible for increasing the current and series connectivity is accountable for increasing the voltage of the PV array.

The equivalent electrical circuit of a single PV cell is illustrated in Fig. 1. A single PV cell can be represented by a diode connected in parallel with a source of current. It also has a series and parallel resistances. The shunt resistance RSH as in [1] is added due to the recombination or leakage of electrons at the junction of the diode and series resistance RS as in [1] is added for the compensation of junction resistance.

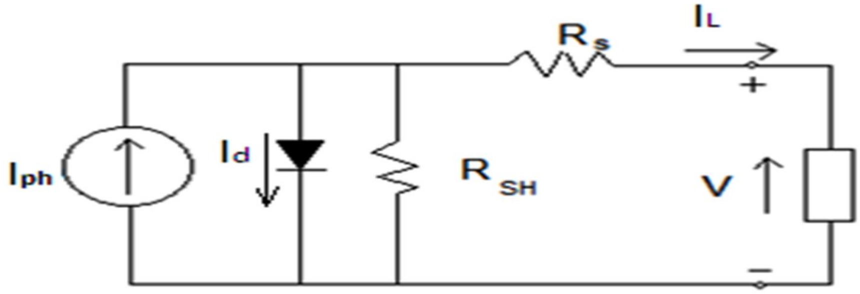

Fig. 1. PV module equivalent circuit diagram

The PV cell output in the form current IL is given by,

$$I_L = I_{ph} - I_d \quad (1)$$

$$I_d = I_0(e^{\left(\frac{qVd}{kT}\right)} - 1) \quad (2)$$

Where

I0 = Reverse saturation current of the diode

q = Electron charge

Vd = Voltage across the diode

k = Boltzmann

T =Temperature in Kelvin (k)

From (1) & (2), we get

$$I_L = I_{ph} - I_0(e^{\left(\frac{qVd}{kT}\right)} - 1) \quad (3)$$

B. CHARACTERISTICS OF A PV ARRAY:

The voltage and current characteristic curves of a PV module are illustrated in Fig. 2.

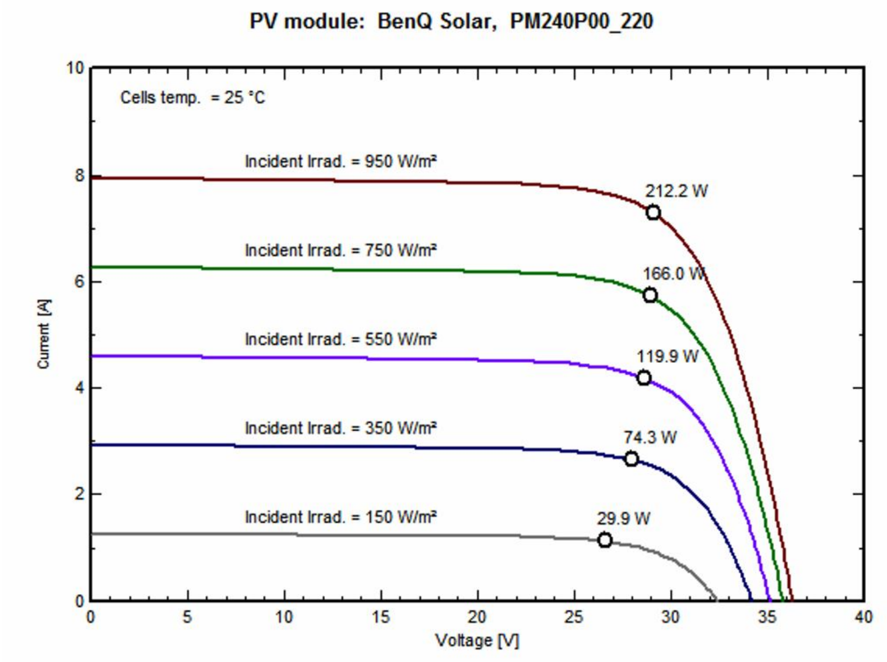

Fig. 2. Voltage-Current characteristic curves of a PV module

It is clear from the Fig. 2, that as the incident solar radiation (INSOLATION) level increases, the maximum current for a PV array also increases and has no significant effect on voltage when the temperature remains constant as in [12].

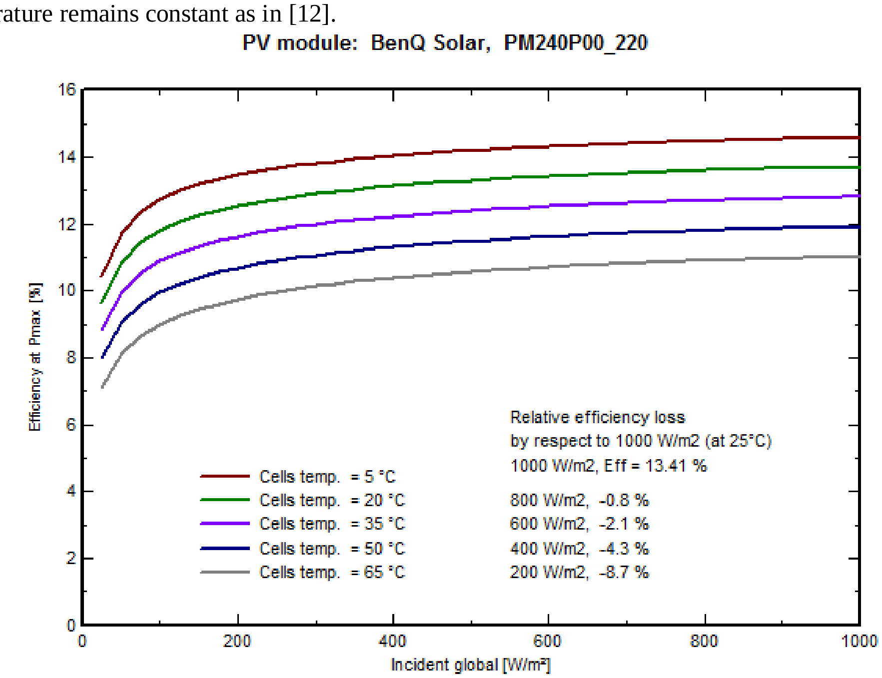

Fig. 3. Efficiency vs. incident global radiation curves

The graph of efficiency versus the incident solar radiation under varying temperature condition is shown in Fig. 3, which clearly demonstrates that as the temperature increases of PV module, the efficiency decreases at specific radiation level.

C. FILLFACTOR (FF):

The PV cell quality can be measured by a parameter known as the fill factor. The fill factor is the ratio of maximum output power (P_{max}) to that of the power output obtained theoretically (P_t). The theoretical power is the product of voltage (Voc) and current (Isc) obtained by open circuiting and short circuiting the PV panel respectively, while P_{max} can be achieved by the multiplication of measured maximum voltage (V_M) and maximum current (I_M). Fill Factor can additionally be seen graphically as the proportion of the two rectangular regions illustrated in Fig. 5.

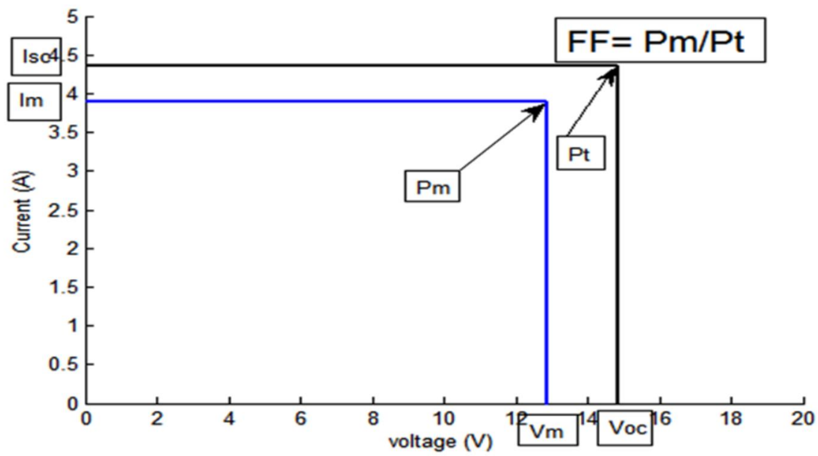

Fig. 5. Fill Factor graphical illustration

Mathematically,

$$Fill\ Factor = P_m / P_t = (I_m . V_m) / (I_{sc} . V_{oc})$$

Usually a higher Fill Factor is required and is also desired. It implies to a voltage and current curves that is generally more like a square. Typically, the range of FF lies between 0.5 to 0.82 if other parameters are kept constant, but ideally for best performance its value should be nearly equal to unity.

III. MAXIMUM POWER POINT TRACKING STRATEGY

In general, electrical power is the combined effect of voltage and current when multiplied together. Fig. 4, shows the power & voltage characteristics curve of PV module. The maximum power points are denoted by empty circles. The power delivered by PV panel at these specific point are maximum due to I_{MP} and V_{MP}. For the location of the MPP several methods are used out of which perturb and observe, Incremental conductance and parasitic capacitance method are the most common methods as in [3].

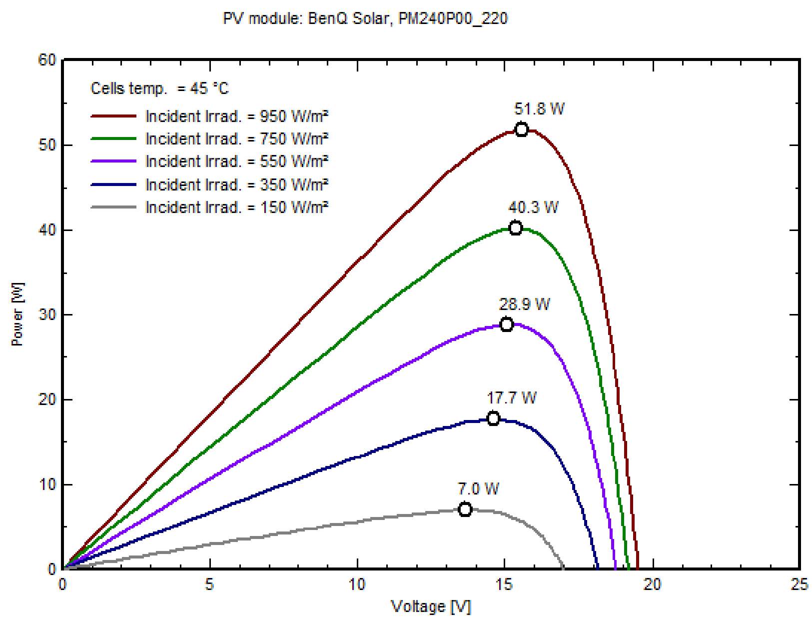

Fig. 4. Power and voltage characteristics curve of a PV module

The MPPT is principally an impedance equalization issue [4] i.e. when the source impedance equals the load impedance, then the power transformation from source towards load will be maximum as described by "maximum power transfer theorem". We can achieve the MPP using a DC-DC converter (Buck or Boost). For instance, if we need to step down the voltage we will use a Buck converter, on the other hand if we needed to increase the voltage we will use a Boost converter according to our load requirements.

IV. PROPOSED STRATEGY FOR ACHIEVING MAXIMUM POWER POINT

The Perturb & Observe Strategy states that a small change in the PV module working voltage causes the following effects [6];

- If the corresponding variations in power ΔP are positive, at that point our change fall towards the maximum power point and we will continue variations in the similar track until MPP is reached.
- If the change in ΔP is negative, this implies that our change are going far as of MPP and so the change in the perturbation direction is needed.

Fig. 6, shows an illustration of the PV panel output power against panel voltage at a given irradiation. The spot indicated shows the MPP. Let us define two operating positions as point A and B. The point A location is such that, as to move closer to the maximum power point by giving the voltage a positive variation. In contrast, the point B locates in such a way around the maximum power point, so as to move nearer to that specific operational point by giving a negative variation to the voltage. The perturbations in either direction by varying the operating voltage are achieved by changing the duty period of a DC converter.

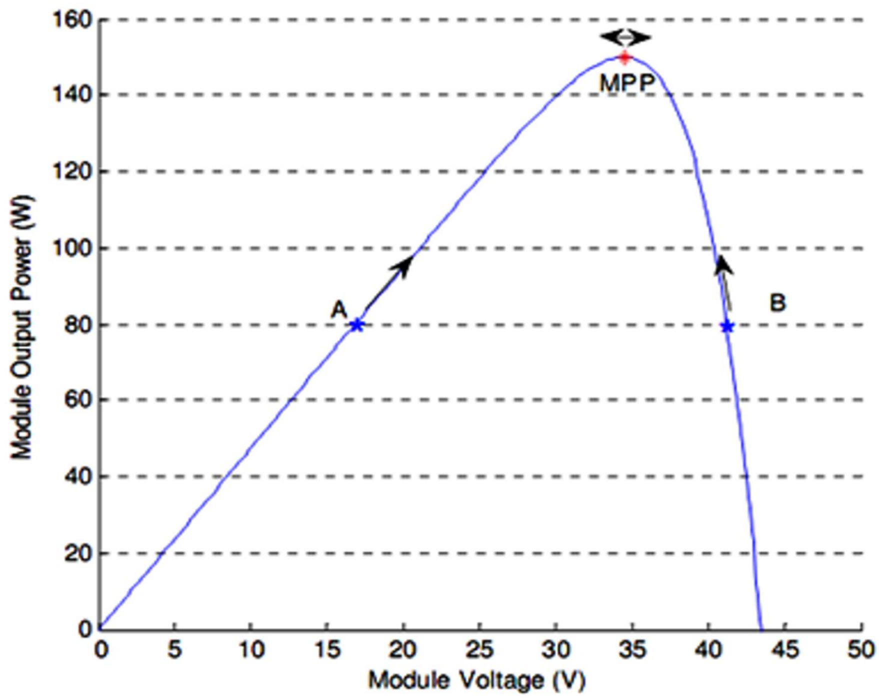

Fig. 6. Power vs. voltage of a PV module

One of the critical weakness of existing P&O method is that, once it reaches MPP than it oscillates around the maximum power point which greatly reduces the efficiency of this method. We can mitigate this drawback through variation in duty cycle and some control mechanism as follows:

- Once the value of ΔP becomes negative than increasing the value of the duty cycle until the ΔP becomes zero which is the required MPP. At this point there will be no oscillation and consequently the problem of oscillation can be solved and during changing weather conditions its efficiency is increased. Fig.8, illustrates the flow chart of our proposed modified P&O technique.

A. MATHEMATICAL MODELLING OF DC-DC CONVERTERS

The objective is to capture the maximum achievable power from PV module. According to the required design objectives, different converter's configuration available can be employed to meet these goals. For different application purposes, a Buck converter can be used to reduce the voltage by a step down process and alternatively Boost converter are used for voltage boosting by the step up process connected in combination with PV array. Some of the principal operational configurations of DC-DC converter are discussed below i.e. Buck converter and Boost converter.

There are two modes of operation in a DC-DC converter

i. Continuous Conduction Mode CCM (Inductor never demagnetize completely)
ii. Discontinuous Conduction Mode DCM (Inductor demagnetize completely)

We will operate the DC-DC converter in continuous mode (CM) to meet our requirements.

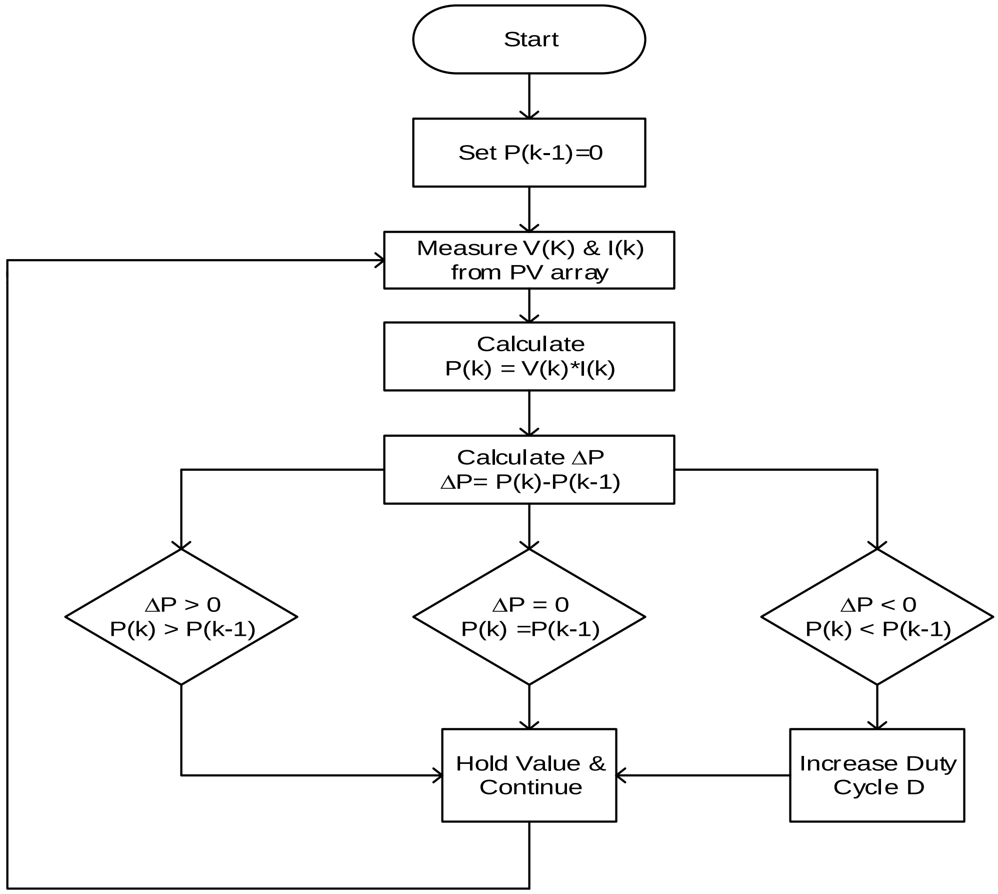

Fig. 8. Proposed modification in Perturb & Observe method.

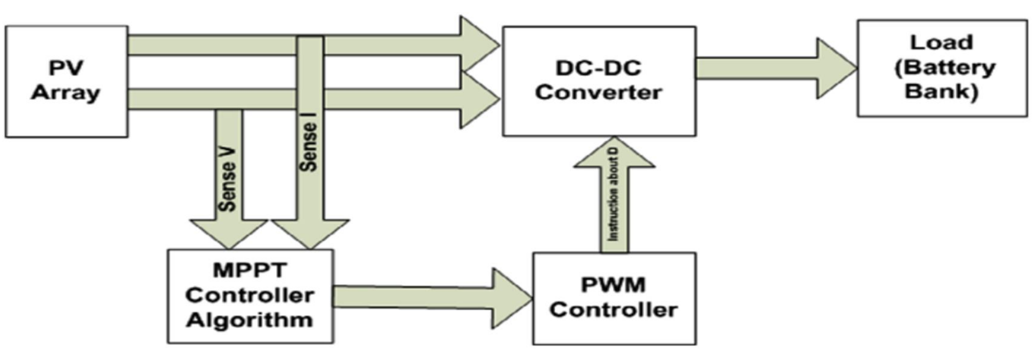

Fig. 9. Block diagram of the complete PV structure with basic MPPT algorithm

B. OPERATION OF BUCK CONVERTER

- Mode 1 operation (When switch is closed)

When the switch (sw_out) is closed; the switch conducts I_L (current across inductor) and the diode turns out to stop conduction due to reverse biased. This brings about a positive voltage V_L over the inductor, which eventually results in a linear amplification in the I_L. At this moment, the capacitor will discharge through the load.

The effective input resistance Ri as in [13], seen by the load is

$$Ri = Vs \;/\; Ia$$

Where

$$Ia = DVs \;/\; R$$

So,

$$Ri = Vs \;/\; DVs \;/\; R$$

$$Ri = R \;/\; D$$

Here,

R = *Load resistance*
D = *Duty cycle*
Vs = *Input voltage*
Ri = *Input resistance*

The above equation shows that the buck converter makes the input resistance Ri as a variable resistance.

The crest-to-crest ripple current [13] of the inductor is given by,

$$\Delta I = V0\, t2 \;/\; L$$

Where

$$t2 = (1 - D)T$$

$$\Delta I = crest - to - crest\ ripple\ current$$

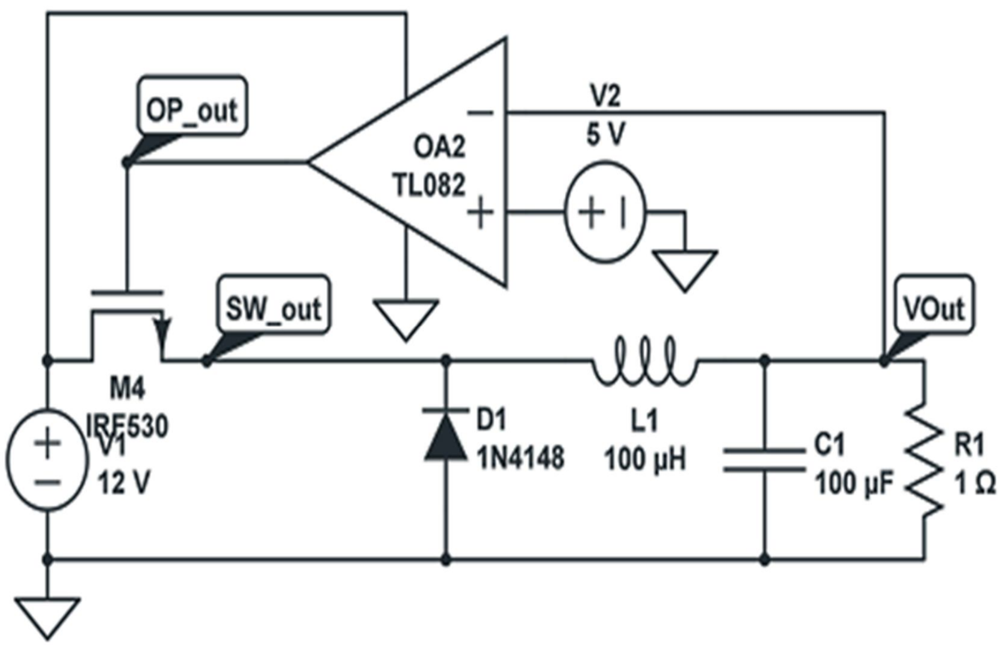

Fig. 9(a). Buck converter circuit diagram

- Mode 2 operation (When switch is open)

In mode 2, when the switch is turned off, because of the inductive energy which is already stored, the inductor current I_L keeps on flowing. Now the current flowing across the diode and also through the load for a time interval of $(1 - D)\,T$, is the I_L. The operation continues, till the switch is closed again and starts conduction.

Fig. 9(b) & 9(c) illustrates the operational outcomes of Buck converter.

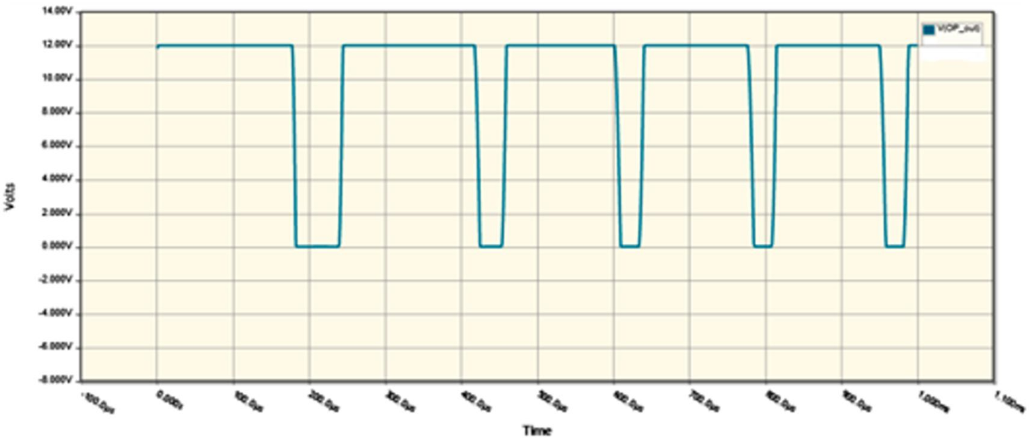

Fig. 9(b). Output Voltage (V_{OUT}) across the load

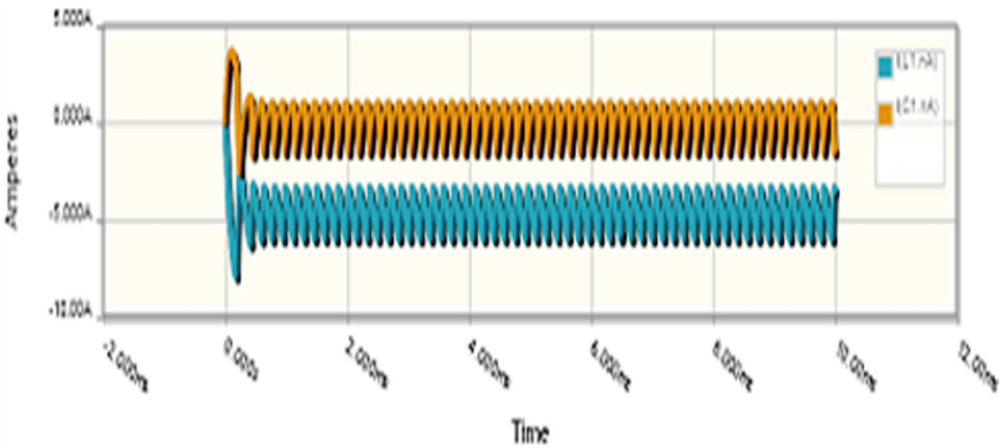

Fig. 9(c). Current curves across capacitor & inductor

C. OPERATION OF BOOST CONVERTER

- Mode 1 (When switch is closed)

Switch $M1$ is closed; the voltage supply continuously charging the inductor and so it accumulates the energy. At this point I_L (inductor current) go up exponentially but for simplification purpose we assume that the charging and discharging of the inductor are linear in nature. The diode $D1$ blocks the current flowing (acts an open circuit) and therefore the load current remains unchanged which is being supplied due to discharging of capacitor $C1$.The output voltage of the boost converter is given by the relation [13],

$$V_0 = V_{in} / 1 - D$$

The peak -to- peak ripple current of the inductor as in [13] is given by,

$$\Delta I = V_{in} D / f L$$

Where,

F = *switching frequency*

L = *Inductance of inductor*

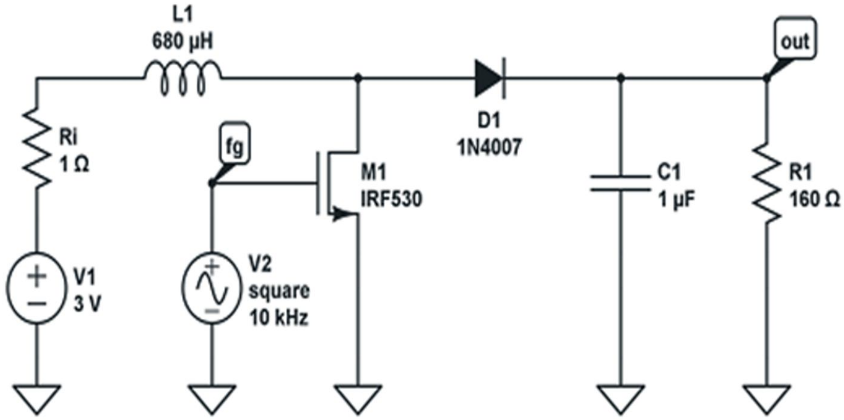

Fig. 10(a). Boost converter circuit diagram

- Mode 2 (when switch is open)

In this mode of operation the switch is open and so the diode becomes short circuited. The energy stored in the Inductor gets discharged through opposite polarities which charge the capacitor C1. Therefore the load current remains constant and in the same direction throughout the operation.

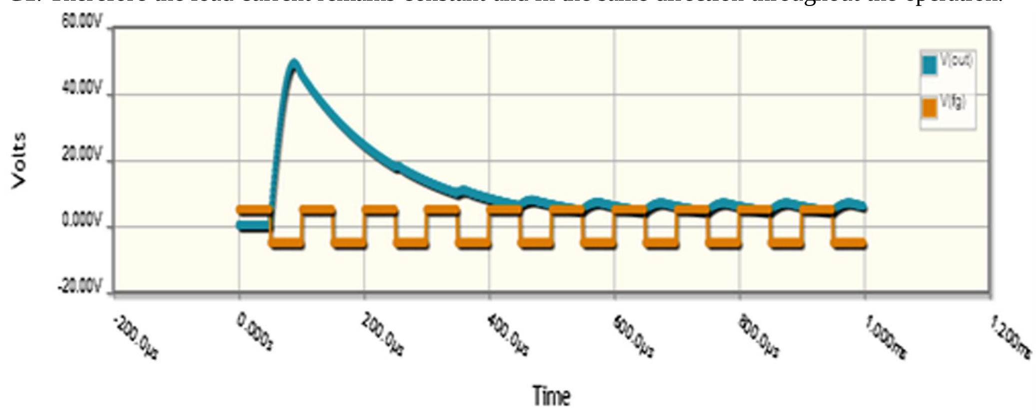

Fig. 10 (b). Voltage characteristics of Boost converter

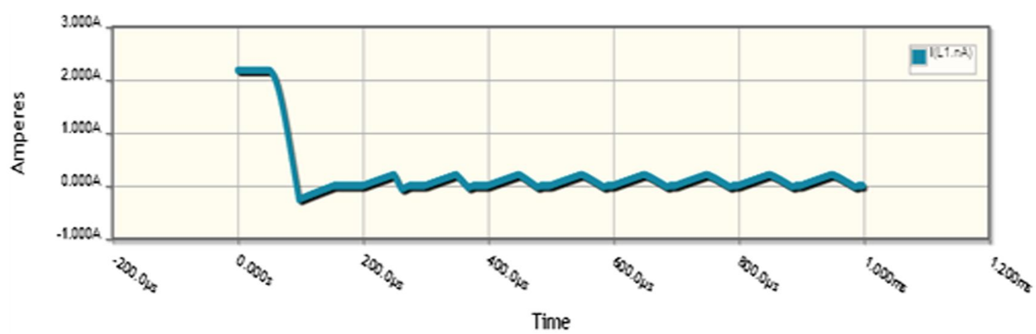

Fig. 10 (c). Inductor current characteristic of Boost converter

V. CONCLUSION

In this paper, we proposed a flowchart based modification model in the existing perturb and observe method. The main drawback of the existing perturbs and observes method is the fluctuation of the output power operational position around the MPP during the steady state. As a result the efficiency of this technique reduces. The main distinction among our suggested method and any other maximum power point locating process is that our proposed method tries to figure out the optimal power location directly through varying the duty cycle of the DC-DC converter. The consequences obtained from such approach obviously indicate that in the configuration of effective MPPT regulators the simplicity and adaptability of perturb & observe maximum power point locating strategy can be utilized by advancing it as per the p requirement. The results obtained can be extended to any other converter scheme as well. The proposed strategy presents some extraordinary preferences relatively, given as: greater effectiveness, high coincidence speed towards the MPP and simple control for the power being withdrawn.

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