

Maximum Power Point Tracking Based on a Modified Perturb and Observe for a Fast Photovoltaic Panel Response

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Abstract—Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the maximum power point(MPP) which depends on panels temperature and on irradianceconditions. The main drawback of P&O is that, the operating point oscillates around the MPP giving rise to the waste of some amount of available energy; moreover, it is well known that the P&O algorithm can be confused during those time intervals characterized by rapidly changing atmospheric conditions. In this paper it is shown that, in order to limit the negative effects associated to the above drawbacks, the P&O MPPT parameters must be customized to the dynamic behavior of the specific converter adopted. A theoretical analysis allowing the optimal choice of such initial set parameters is also carried out. The fast convergence of the proposal is proven.

Keywords— P&O, Taylor's series, MPPT, Photovoltaic panel

I. Introduction

Solar panel is the fundamental energy conversion component of photovoltaic (PV) systems. Its conversion efficiency depends on many factors, such as insolation levels, temperature, and load condition. The algorithms that are most commonly used are the perturbation and observation method, dynamic approach method and the incremental conductance algorithm.

Photovoltaic (PV) generation systems are actively being promoted. PV generation systems have two big problems, namely;

- the efficiency of electric power generation is very low, especially under low radiation states
- the amount of electric power generated by solar arrays is always changing with weather conditions, i.e., irradiation.

Therefore, a maximum power point tracking (MPPT) control method to achieve maximum power output at real time becomes indispensable in PV generation systems. Till date several MPPT techniques have been proposed and some among those are also implemented on hardware platform.

A maximum power point tracker is used for obtaining the maximum power from the solar PV module and conversion to the load. A non isolated DC-DC converter (step up/ step down) offers the purpose of conversion maximum power to the load. A DC-DC converter acts as an interface between the load and the module. By varying the ratio of duty cycle the impedance of load as it appears by the source is varied and matched at the peak power point with the source so as to conversion the maximum power

The problems with the conventional perturb and observe algorithm and that of incremental conductance is their slow response in reaching to the maximum power point. And hence to overcome the problem of slow response a new algorithm has been developed. In this paper, a new MPPT technique is proposed which suggests a modified perturb and observe algorithm to reach fast to the MPP compared to the conventional perturb and observe technique. This paper explains the PV equivalent circuit, current-voltage, power-voltage characteristics of photovoltaic systems and the operation of the some commonly used MPPT techniques. A new perturbation and observation algorithm has been formed and has been validated with the help of practical data along with modeling and the results of simulations which compare its performance with that of algorithms of conventional P&O technique.

Many PV cell models are investigated by the researchers, and the most used is that detailed in the equation [1].

Due to its non-linear (1), photovoltaic cells can produce maximum power point MPP Fig.1.a, for optimum voltage and current (3)

$$I = I_{ph} - I_o \left[e^{\frac{(V+IR_s)q}{akT_{cr}}} - 1 \right] - \frac{(V + IR_s)}{R_{sh}} \quad (1)$$

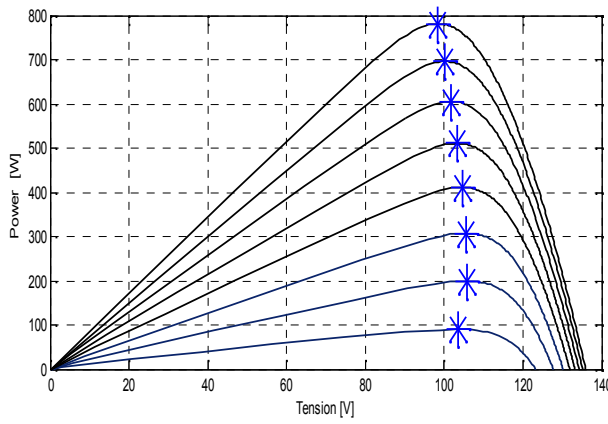
Where

I_{sh} and I_D are the photo generated current and the dark saturation of the PV source.

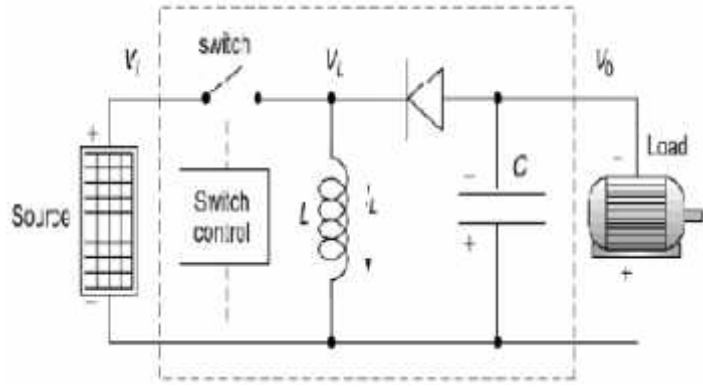
R_s and R_{sh} are cell series and parallel resistances respectively. This MPP changes with the irradiation value Fig.1.a, the I-V characteristic for P_{max} Fig.1.b implies the use of a buck-boost chopper as an interface between the PV generator and the

battery [2-3], because in the morning the battery imposes an important storage current so the current should be limited, and in the end of the daylight the storage current became weak so the PV voltage became greater than the battery voltage which should be limited.

The chopper guaranties a maximum power delivered by the PV panel [4], this chopper has its own power consumption. The PV maximum power controller do not guaranties a maximum charging power. To transmit the maximum power to the battery [5] the chopper parameters (R_c - adjustable resistance control) must be introduced in the novel MPPT.



a./



b./

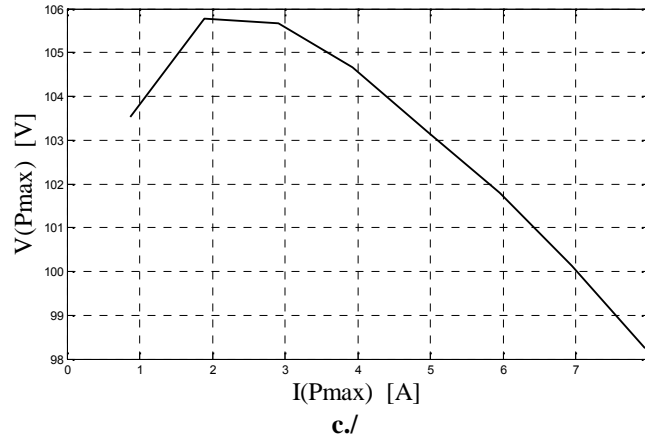


Fig.1 PV cell's power characteristics (a) and MPP (b)

Resistance R_c is used to vary the output parameters of PV cells to reach the MPP. Generally the chopper is assumed as a variable resistor. Now the MPPT circuit is supplied with the PV module. This circuit provides the user with the reference values V_{op} and I_{op} . Several MPPT techniques has been proposed by researchers for the detection of this operating point, as the derivative method, artificial intelligence, the method perturb & observe, etc ... For all these techniques the principle is the same

In this work, the solar panel is used to charge a Lithium battery, which will be reused to power a DC load. To ensure proper control of the system, the modeling of different elements is necessary.

There are several configurations modeling the Lithium batteries [6] (e.g. distributed constant model based on the model of the power lines). The model accepted by most researchers [7] is the one shown below (1)

What we noticed during the association panel PV- chopper Battery, MPP shifts. So in order to readjust to the new MPP, the next development was done in order to give the new reference values of voltage and current.

$$\frac{dP_{PV}}{dt} = 0 \quad \text{- Determines the value of } I_{OP1}, \text{ therefore } V_{OP1}.$$

With the inclusion of the Lithium battery (2) this relationship becomes incomplete. It is requested that the PV panels transfer the maximum power to the Batteries.

$$P_{PV} = dP_C + P_B \quad (2)$$

With

P_{PV} –Delivered photovoltaic panel power

dP_C – power loss at the chopper

P_B – the power transferred to the Lithium battery

$$\text{Than } P_B = P_{PV} - r_C I^2$$

To find the operating point ensuring maximum loading to the battery (3), $dP_B/dI = 0$, we proceed as follows.

$$P_B = IV_B = R_B I^2$$

$$P_B = R_B \left\{ I_{ph} - I_o \left[e^{\frac{(R_B+r_C+R_S)Iq}{akT_C T}} - 1 \right] - \frac{(R_B+r_C+R_S)I}{R_{Sh}} \right\}^2 \quad (3)$$

Due to the nonlinearity of the function (3) researchers use numerical methods, whose main drawback is the time required for the determination of optimal points is relatively slow. Knowing that, the position and intensity of solar radiation varies. Generally in the implementation the tracker's starting point is taken as the set rated value.

II. Maximum Power Point Tracking MPPT

Maximum Power Point Tracking is used to automatically find the voltage (VMPP) or current (IMPP) at which a PV array should operate to obtain the maximum power output under a given temperature and irradiance. And some particular situations as, partial shading conditions, it is possible to have multiple local maxima, but overall there is still only one true MPP.

II.1. Several methods are proposed in literature

a. Indirect Methods

For the indirect methods the MPP is estimated from

- Voltage
- Current

- The irradiance
- Using empirical data
- Mathematical expressions of the numerical approximation

The estimation is carried out for a specific PV generator installed in the system. Because Prior evaluation of panel, based on mathematical relationships, Database not valid for all operating and meteorological conditions

b. Direct Methods

For the direct methods only voltage and/or current information is used. Prior knowledge of PV panel is not required; it is independent of isolation, temperature and degradation levels.

c. Fractional Open-Circuit Voltage

This technique exploits the advantage of the near linear relationship between V_{OC} and V_{MPP}

$$V_{MPP} \approx K_V \cdot V_{OC} \quad (4)$$

Where k_V is a constant of proportionality (0.71-0.78) and depends on the characteristics of the PV array being used, and should be computed beforehand empirically. The V_{MPP} and V_{OC} defined for specific PV array at different irradiance and temperature. Once k_V is known, V_{OC} is measured by shutting down the converter, periodically.

d. Perturb & Observe Technique

Incrementing the voltage increases the power when operating on the left of the MPP and decreases the power when on the right of the MPP. Perturb and observe method can fail under rapidly changing atmospheric conditions. If the irradiance

increases and shifts the power curve the operating point will move. And the P&O process is repeated periodically until the MPP is reached. The system then oscillates regarding this new MPP. This undesired oscillation can be minimized by reducing the perturbation step size. Smaller perturbation size slows down the MPPT. Or variable perturbation size towards the MPP. In this case many works use fuzzy logic control is used to optimize the magnitude of the next perturbation. For some application we do not agree with the fuzzy logic technique, because most implementations are build around PIC controller, unfortunately this last technique uses a lot of resource and memory space that slows the microcontroller.

III. Improvement Perturb and observe technique

The techniques disturb and observe is the most used for its simplicity, based on the increment and decrement the reference, and then the operating point oscillates around the MPP. But it has some drawbacks that can make or diverge significantly reduce the transmit power. If the step size is large, the MPPT algorithm will respond quickly to sudden and rapid changes in operating conditions but with losses. If the step width is very small losses will be reduced, but the system has a slow response to rapid changes in temperature or irradiation.

To economically meet this constraint, we propose for the determination of the MPP a Taylor series representation of the exponential part (5), which gives a good approximation from $n = 3$ [8].

r_c represents the resistance grouping all the power losses in the chopper, and R_B is the resistance of the battery depending on charging status of the battery (battery in max discharged $R_B = 0$, and Battery in full charge $R_B = R_{B_{full}}$).

The optimum is found if equation (6) is satisfied.

$$P_B = R_B \left\{ I_{ph} - I_o \left[\sum_{n=0}^{\infty} \left(\frac{(R_B + r_c + R_S)q}{akT_{CT}} \right)^n \frac{I^n}{n!} - 1 \right] - \frac{(R_B + r_c + R_S)I}{R_{Sh}} \right\}^2 \quad (5)$$

$$dP_B/dI = 2R_B I \left\{ I_o \left[\sum_{n=0}^{\infty} n \left(\frac{(R_B + r_c + R_S)q}{akT_{CT}} \right)^n \frac{I^{n-1}}{n!} \right] - \frac{(R_B + r_c + R_S)}{R_{Sh}} \right\} = 0 \quad (6)$$

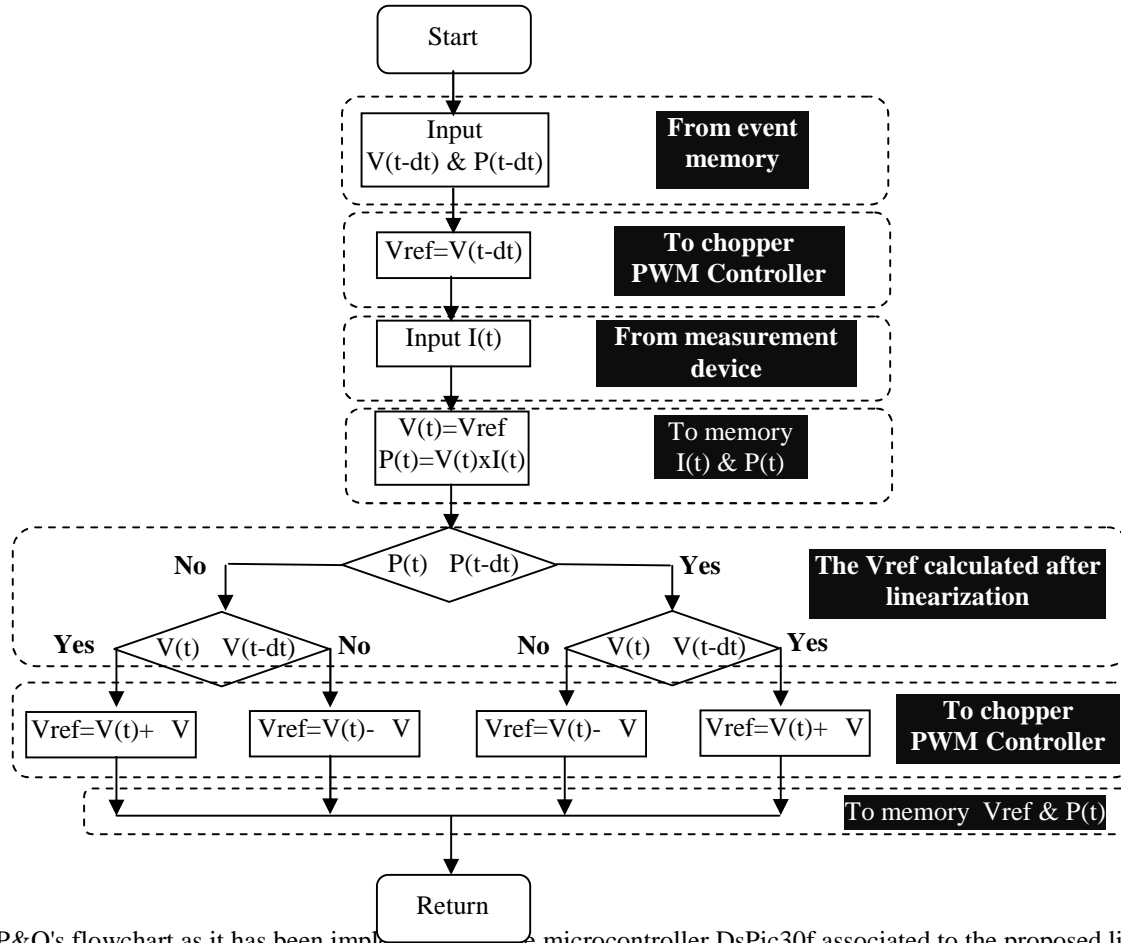


Fig.2 P&O's flowchart as it has been implemented in the microcontroller DsPic30f associated to the proposed linearization

Two solutions are possible: $I=0$ can not be taken, or the second part equals zero (7). For $n=3$ we can write

$$AI_o + A^2I_o I + A^3I_o \frac{I^2}{2} - B = 0 \quad (7)$$

The coefficients A and B are constants to be determined and depend on the type of PV module used and the charging state of the battery.

Because the checked current is positive, the optimum currents OP can be find as fellow (8)

$$I_{OP} = \frac{1}{A} \left[-1 + \sqrt{\frac{2B}{AI_o} - 1} \right] \quad (8)$$

Now the comparison between the two MPPs is possible (9), replacing the corresponding values of coefficients A and B for respectively OP1 and OP2 one can write:

$$I_{OP1} = \frac{akT_{CT}}{(R_B + R_S)q} \left[-1 + \sqrt{\frac{2akT_{CT}}{qR_{sh}I_o} - 1} \right] \quad (9.a)$$

$$I_{OP2} = \frac{akT_{CT}}{(R_B + r_c + R_S)q} \left[-1 + \sqrt{\frac{2akT_{CT}}{qR_{sh}I_o} - 1} \right] \quad (9.b)$$

These currents are used in the equation as an initial value (near the true MPP) in order to fast reach the real optimal point Fig.2.

It is observed Fig.3 the effect of radiation is higher on IOP than on VOP for this reason we chose an optimization algorithm based on the current parameter IOP to ensure better accuracy of the MPP.

Thanks to this new optimization MPP, part of the power consumed by the chopper is transferred to the battery Fig.4 the energy benefit is clearly shown by P_{BG} (battery power gain)

In order to show the efficiency of the battery MPP will be compared to that given by the designer (PV MPP). The new proposed MPP permits a better transmitted average power to the load (Battery) Fig.5.

For the same light quality the proposed algorithm offers an optimal power use reached by the new optimal voltage and current references Fig.6.

Often the reference point is far from the optimum maximum power point, although we use fast components such as dsPIC30F in our case, according to the selected step, the system no longer follows the variation of irradiation (very slow response) or fast but inaccurate. So the proposed linearization allows choosing a reference very close to the optimum. The increment can be taken very short, so fast and accurate.

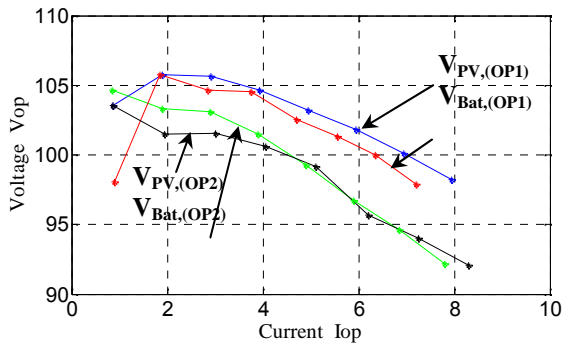


Fig.3 optimal currents and voltages references for MPP1 & 2

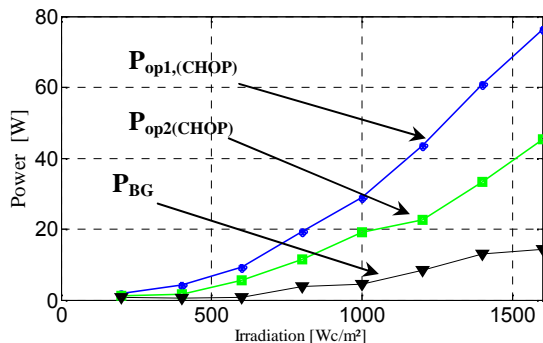


Fig.4 the power chopper consumption

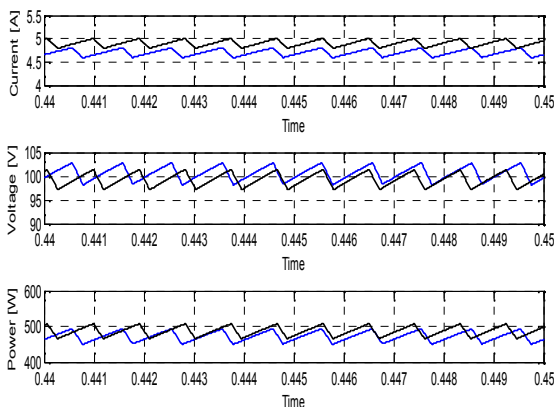


Fig.5 Battery current, voltage and power

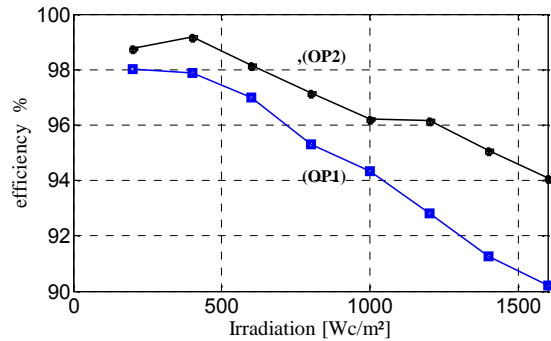


Fig.6 The proposed technique efficiency

Furthermore the speed convergence to the desired power the proposal offers more efficiency of all the system Fig.6.

IV. Conclusion

Perturb and observe technique is very useful but not accurate. So, the Taylor's series development was used to define an analytical formulation of a preset incremental values in order to performs the convergence of the P&O MPPT. thanks to the improvement made to the P & O technical, microcontroller is less stressed, uses less memory space and more accurate in the maximum power point tracking.

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