Le 3ème Séminaire International sur les Energies Nouvelles et Renouvelables
The 3nd International Seminar on New and Renewable Energies
Unité de Recherche Appliquée en Energies Renouvelables, Ghardaïa – Algérie 13 et 14 Octobre 2014

Improvement Perturb and Observe for a fast response MPPT applied to photovoltaic panel

Labar Hocine, Kelaiaia Mounia Samira, Mesbah Tarek, Kelaiaia samia

University of Badji Mokhtar Annaba; Algeria
Faculty of Engineering Sciences
Department of Electrical Engineering
Laboratoire d'electrotechnique d'Annaba
hocine.labar@univ-annaba.dz

***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 irradiance conditions. 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. PV PANEL AND BATTERY MODELING

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)

$$I = I_{ph} - I_o\left[e^{\frac{(V+IR_S)q}{akT_{CT}}} - 1\right] - \frac{(V+IR_S)}{R_{Sh}} \qquad (1)$$

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 (Rc - adjustable resistance control) must be introduced in the novel MPPT.

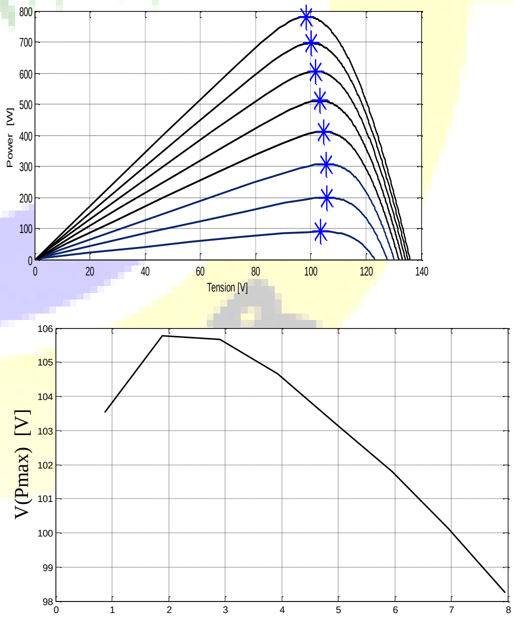
a./ b./


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

Resistance Rc 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 Vop and Iop. 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.

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

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

With

P_{PV} –Delivered photovoltaic panel power
dP_C – power loss at the chopper
P_B – the power transferred to the Lithium battery

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.

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

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

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}

$$V_{MPP}\approx K_V.V_{OC} \qquad (4)$$

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.

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

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

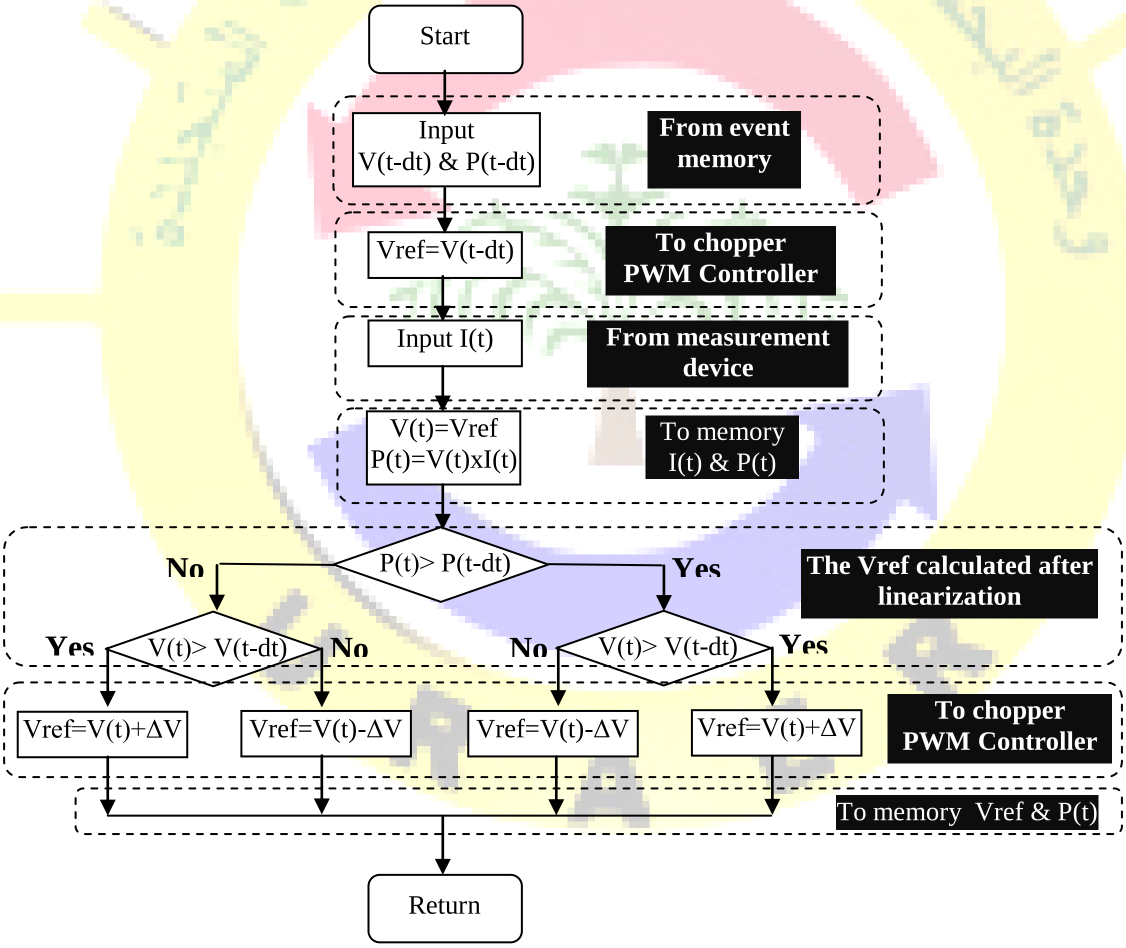


Fig.2 P&O's flowchart as it has been implemented in the microcontroller DsPic30f associated to the proposed linearization

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].

rc 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 $R_B \rightarrow 0$, and Battery in full charge $R_B \rightarrow \infty$).

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

Two solutions are possible: I=0 can note be taken, or the second part equals zero (7). For n=3 we can write

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

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)

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

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:

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

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

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.

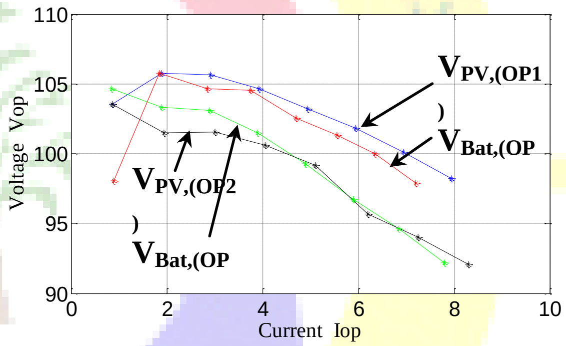


Fig.3 optimal currents and voltages references for MPP1 &2

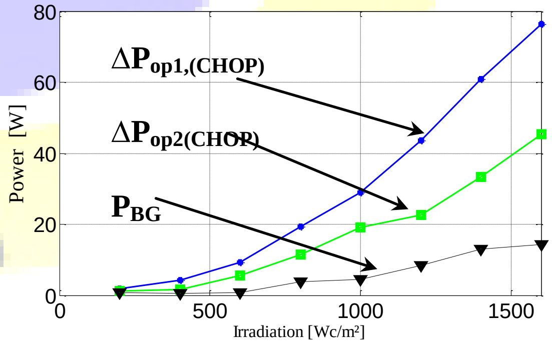


Fig.4 the power chopper consumption

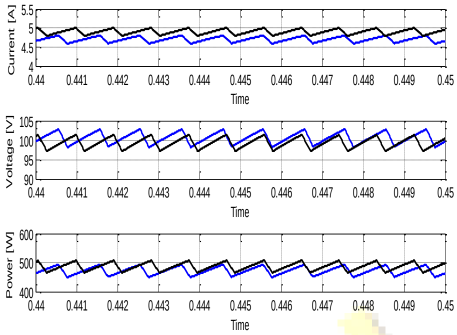


Fig.5 Battery current, voltage and power

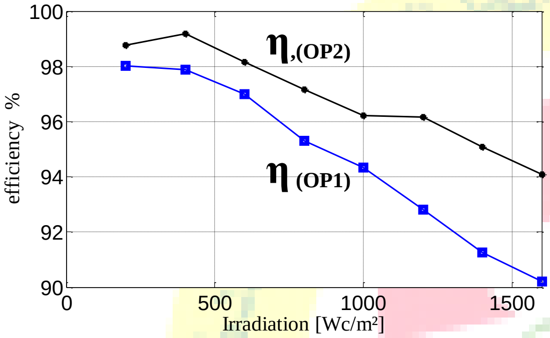


Fig.6 The proposed technique efficiency

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.

References

[1]- Chia-Hung Lin, Cong-Hui Huang, Yi-Chun Du, Jian-Liung Chen "Maximum photovoltaic power tracking for the PV array using the fractional-order incremental conductance method" *Applied Energy, Volume 88, Issue 12, December 2011, Pages 4840-4847*

[2]- Emilio Mamarelis, Giovanni Petrone, Giovanni Spagnuolo "A two-steps algorithm improving the P&O steady state MPPT efficiency" *Applied Energy, Volume 113, January 2014, Pages 414-421*

[3]- Zainal Salam, Jubaer Ahmed, Benny S. Merugu "The application of soft computing methods for MPPT of PV system: A technological and status review" *Applied Energy, Volume 107, July 2013, Pages 135-148*

[4]- Tingshu Hu, Hoeguk Jung "Simple algorithms for determining parameters of circuit models for charging/discharging batteries" *Journal of Power Sources, Volume 233, 1 July 2013, Pages 14-22*

[5]- Hongwen He, Rui Xiong, Hongqiang Guo, Shuchun Li "Comparison study on the battery models used for the energy management of batteries in electric vehicles"*Energy Conversion and Management, Volume 64, December 2012, Pages 113-121*

[6]- Bin-Juine Huang, Po-Chien Hsu, Min-Sheng Wu, Chun-Wen Tang "Study of system dynamics model and control of a high-power LED lighting luminaire" *Energy, Volume 32, Issue 11, November 2007, Pages 2187-2198*

[7]- Stanley K.H. Chow, Danny H.W. Li, Eric W.M. Lee, Joseph C. Lam" Analysis and prediction of day lighting and energy performance in atrium spaces using daylight-linked lighting controls" *Applied Energy, Volume 112, December 2013, Pages 1016-1024*

[8]- Shu-xian Lun, Cun-jiao Du, Ting-ting Guo, Shuo Wang, Jing-shu Sang, Jia-pei Li "A new explicit *I–V* model of a solar cell based on Taylor's series expansion" *Solar Energy, Volume 94, August 2013, Pages 221-232*