International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-3 Issue-4, September 2013

Modeling and Optimization of a Photovoltaic Generator with Matlab/Simulink

Ahmed Yahfdhou, Abel Kader Mahmoud, Issakha Youm

***Abstract*—The output power of a photovoltaic generator is related to many climatic factors like temperature and solar illumination; it is then necessary to track the maximum power point in real time to optimize the photovoltaic system efficiency. This work presents the modeling of a photovoltaic system with a maximum power point tracking (MPPT). The operating of the photovoltaic system and the improvement of its efficiency taking into account rapid variations of meteorological conditions is presented with a MPPT based on perturb and observe (P&O) strategy, both implemented using Matlab. Simulation results showed that operating point oscillates around maximum power point and these oscillations are proportional to the variations of the incident illumination.**

***Index Terms* — photovoltaic generator, MPPT, Matlab**

I. INTRODUCTION

Electrical energy needs are still increasing overthese last years but production constraints like pollution [1] and global warming [2] lead to development of renewable energy sources, particularly photovoltaic energy. Due to very limited conversion efficiency [3], it is necessary to optimize all the conversion chain and specifically DC-DC converters by use to maximum power point tracking strategies [4] (figure 1).

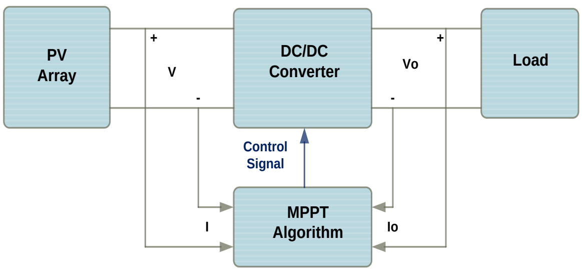

Figure 1: Block diagram of typical MPPT system**.**

II. PHOTOVOLTAIC GENERATOR MODELING

Photovoltaic generatorsconsist usually of several modules interconnected in series and parallel for a given operating voltage an output power [5]. Photovoltaic generators modeling can then be deduced from those of solar cells; many studies have been already proposed using onediode or more precise two diodes models. In this paper we use the conventionalsingle diode model presented on (figure 2).

Manuscript published on 30 September 2013.
***Correspondence Author(s)**
Mr. Ahmd Yahfdhou, Physics Department, FST-UCAD, Dakar, Senegal.
Prof. Abel Kader Mahmoud, PhysicsDepartment, FST-UN, Nouakchott, Mauritania,
Prof. IssakhaYoum, Physics Department, FST-UCAD, Dakar, Senegal.

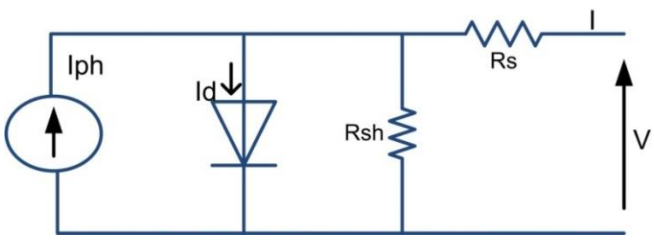

Figure 2: Conventional single diode model.

I_{ph} is the photogenerated current related to the illumination level, I_d the diode current, R_{sh} and R_s are respectively the shunt and series resistances.
Based on (figure 2), the output voltage and current dependence can be written in the form [6]:

$$I = I_{ph} - I_0\left(e^{\frac{V+R_sI}{V_t}} - 1\right) - \frac{V+R_sI}{R_{sh}} \quad (1)$$

- Vt is the thermal voltage written as: Vt= (A*K*T)/q where A is the ideality factor, K the Boltzmann constant, T the temperature of the cell and q the elementary charge.
- I0 is the dark current.

Compared to the measured photocurrent I_{ph_ref} at standard tests conditions (STC: G_{ref} =1000W/m², T_{ref} =25°C), the photocurrent at another operating conditions can beexpressed as:

$$I_{ph} = \frac{G}{G_{REF}}\left[I_{PH,REF} + \alpha(T - T_{REF})\right] \quad (2)$$

G is thesolar irradiance, α is the short circuit current temperature coefficient.
I_{ph_ref} can be taken to be the short current at STC (I_{cc_ref}), I_{cc_ref} and α are generally given by solar module manufacturer. In the case where the cell temperature T_{amb}not is determined directly by a temperature sensor, it can be deduced from the following relation:

$$T = T_{amb} + \left[\frac{N_{oct} - 20}{800}\right]G \quad (3)$$

T_{amb} is the ambient temperature, N_{oct} is the normal operating cell temperature given in most cases by the manufacturer. For the dark current I_0 and we can write:

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

$$I_0 = I_{0,REF}\left(\frac{T}{T_{REF}}\right)^{3/A}\exp\left[\frac{qE_g}{AK}\left(\frac{1}{T_{REF}}-\frac{1}{T}\right)\right] \quad (4)$$

$I_{0,ref}$ is the dark current at STC and E_g is the forbidden band energy.

In the single diode model, we assumed R_{sh} to be infinite; the series resistance can be derived in the form [6]:

$$R_s = -\frac{dV}{dI_{(Voc)}} - \frac{AKT/q}{I_0\exp\left(\frac{qV_{OC}}{AKT}\right)} \quad (5)$$

Equation (1) can be solved by numerical method likeNewton Raphsons [5].

$$X_{n+1} = X_n - f(X_n)/f'(X_n) \quad (6)$$

III. MAXIMUM POWER POINT TRACKING

The maximum power point tracking is a very difficult task essentially because the photovoltaic generator I-V curve depends on both incident power and operating temperature. Many methods have been proposed [6]-[8], but perturb &observe (P&O)method seems to be most used one [9]-[11]. The P&O is an iterative techniquethat perturbsphotovoltage Vpv and analyses the behavior of the resulting power as presented on figure 3.

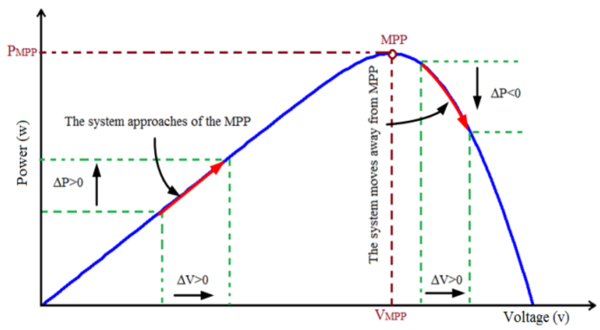

Figure 3: Behavior of P&O MPPT algorithm with P-V curve.

For an increment in Vpv, if the output power ΔPs greater than zero (Vpv>0), we are moving to maximum power point MPP; if ΔP <0 then we are moving away of the MPP. In each case, the control algorithm is presented on figure 4.

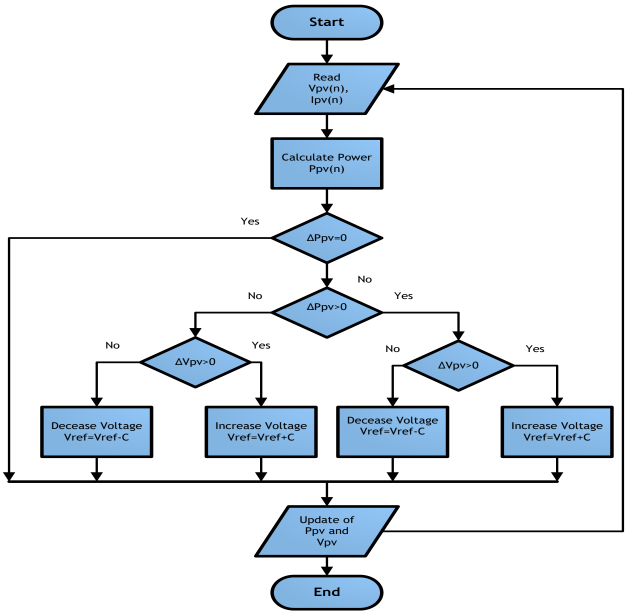

Figure 4: Algorithm diagram of perturb &observe (P&O)method.

IV. SIMULATION RESULTS AND DISCUSSIONS

The whole simulation is based on experimental data ofsolar irradiance and temperature for a day at Nouakchott (fig. 5).

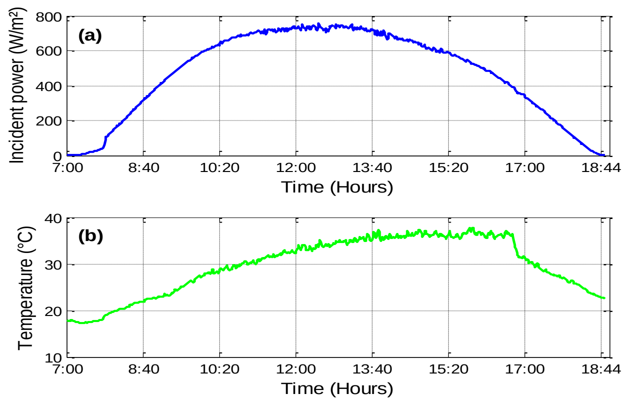

Figure 5: Solar irradiance (a) and temperature (b) at Nouakchott in February.

Figure 6:Shows the I-V and P-V curves of the photovoltaic generator under different levels of illumination.

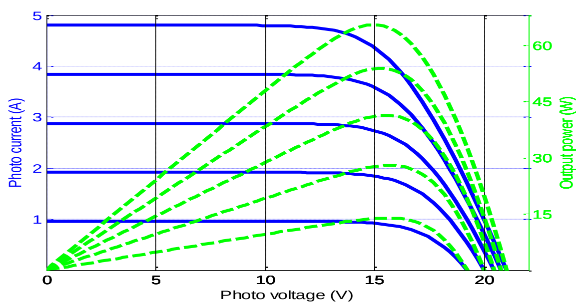

Figure 6: Irradiance dependence of I-V and P-Vcharacteristics of a PV generator.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

As it can be seen from this figure, the short circuit current is directly proportional to the irradiance contrary to the open circuit voltage variation much smaller (it depends logarithmically on the irradiance).

Figure 7 illustrates the influence of the operating temperature on the I-V curve.

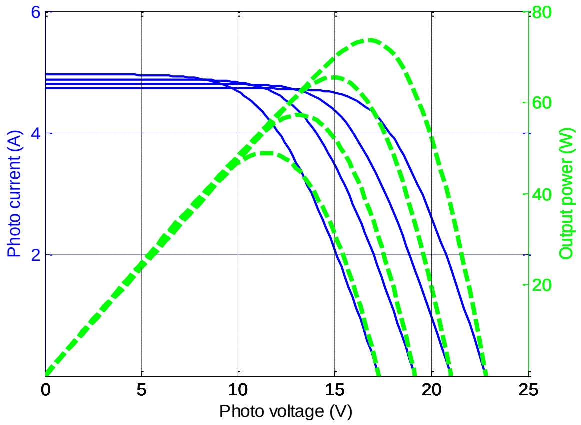

Figure 7: Temperature effect on the I-V and P-V curves.

The most significant is the temperature dependence the open circuit voltage which decreases with increasing temperature.

The transmission of electric current produced by the PV generator involves ohmic losses. These can be grouped together and included as a resistance in the equivalent circuit (fig. 2). It is seen that the series resistance affects the PV generator operation mainly by reducing the fill factor (figure. 8).

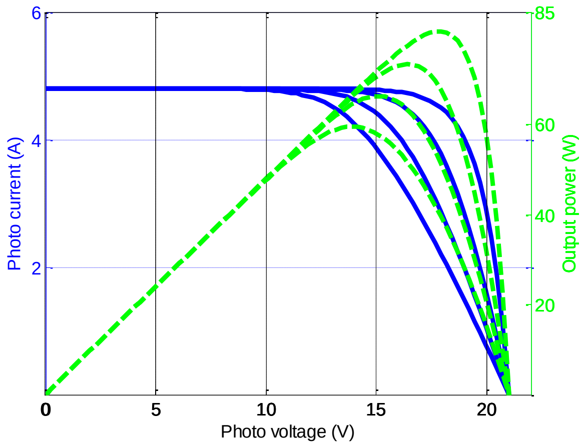

Figure 8: effect of the series resistance on the I-V and P-V curves.

Thisalso explains whenincreasing series resistance, the voltage across the cell decreases rapidly.

The profile of the P-V curve and the I-V curve is presented to exhibit the efficiency of the control algorithm (figures 9 and 10) when tracking the MPP.

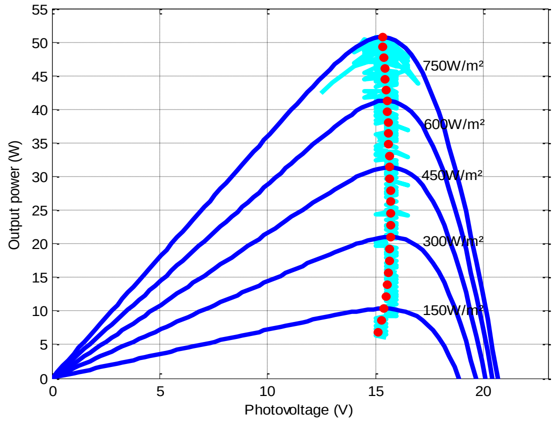

Figure 9: P-V curve and calculated maximum power point (MPP).

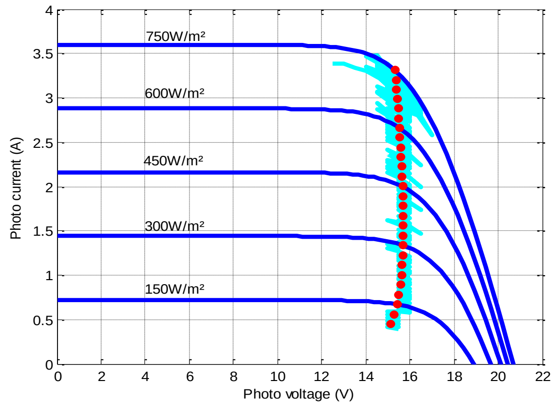

Figure 10: I-V curve and calculated V_{MPP} and I_{MPP}.

According to these figure, it can be seen that despite variation of operating conditions, our technique tracks is very efficiency the maximum power point. This efficiency can be calculated from equation following [12]:

$$\alpha_{MPPT} = \frac{\int_0^t Pact(t)dt}{\int_0^t P\max(t)dt} \quad (7)$$

Pact is the output power of the photovoltaic generator with P&O algorithm and Pmax is the maximum is the maximum theoretical power that can be produced by the photovoltaic generator. Figure 11 exhibits the comparison between Pact (P&O) and Pmax.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

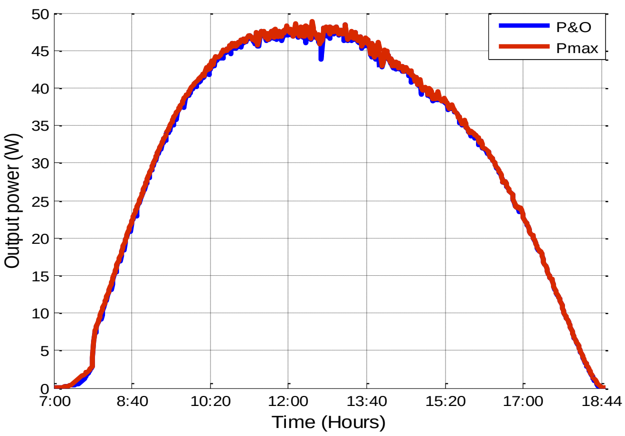

Figure 11: Comparison of the theoretical maximum power and the maximum power (P&O).

A very good agreement is obtained between the theoretical maximum output power and the maximum power calculated by mean of the P&O technique based on Nouakchott meteorological conditions. This agreement can be seen directly with the efficiency of the control algorithm on figure 12.

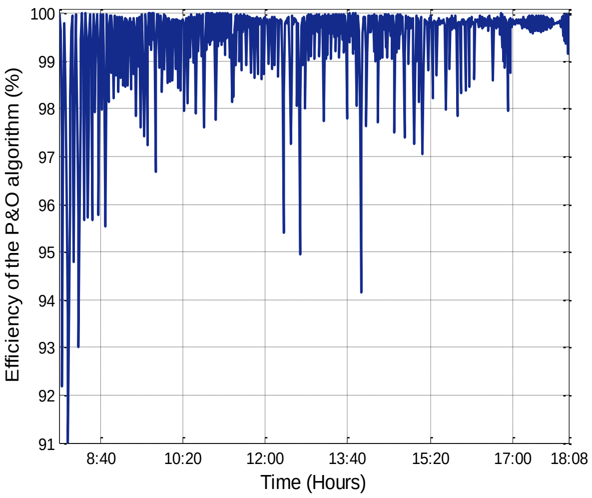

Figure 12: Efficiency of the maximum power point tacking (P&O).

The obtained efficiency is near 99, 5% leading to a very efficiency control technique.

V. CONCLUSION

We presented in this study a mathematical model in order to simulate the behavior of a photovoltaic generator in a reel operating conditions.

Based on this model, we exhibited the effects of incident power, temperature and series resistance on both I-V curve and P-V curve. We also proved that perturb and observe algorithm is an efficient technique to optimize the operating of a photovoltaic generator.

REFERENCES

1. Askarzadeh, A. Razazadeh, “Extraction of maximum power point in solar cells using bird mating optimizer-based parameters identification approach”, Solar Energy 90, pp. 123-133, 2013.
2. M. R. Alrashidi, M. F. Alhajri, K.M. El-naggar, A. K. Al-othman, “A new estimation approach for determining the I-V characteristics of solar cells”, Solar Energy 85, pp. 1543-1550, 2011.
3. M. Seifi, A. B. Chesoh, N. I. Abdwahab, M.KB. Hasan, “A comparative study of PV models in Matlab/Simulink”, Word Academy of Science, Engineering and Technology 74, pp. 108-113, 2013.
4. M. Yahya, I. Youm, A. Kader, “Behavior and performance of a photovoltaic generator in real time”, International Journal of the Physical Science 6(18),pp. 4361-4367, 2011.
5. D. Bonkoungou, Z. Koalaga, D. Njomo, “Modeling and simulation of photovoltaic module considering single-diode equivalent circuit model in Matlab”, International Journal of Emerging Technology and Advanced Engineering 3(3), pp. 493-502, 2013.
6. Salas, E. Olias, A. Barrado, A. Lazaro, “Review of the maximum power point tracking algorithms for stand-alone photovoltaic systems”, Solar Energy Material & solar cells 90, pp.1555-1578, 2006.
7. T. Papaioannou, A. Purvins, “Mathematical and graphical approach for maximum power point modeling”, Applied Energy 91, pp. 59-66, 2012.
8. B. Amrouche, A. Guessoum, M. Belhamel, “A simple behavioral model for solar module electric characteristics based on the first order system step response for MPPT study and comparison” Applied Energy 91, pp. 395-404, 2012.
9. N. Femia, G. petrone, G. Spagnulo, M. Vitelli, “Optimization of perturb and observe maximum power point tracking method”, IEEE Transactions on power Electronics 20, pp. 963-973, 2005.
10. S.Lal, R.Dhtash, S.Sinha, “Analysis different MPPT technique for photovoltaic system, International Journal of Engineering and Innovative Technology 06, pp. 1-3, 2012
11. Yadav, S. Thirumaliah, G. Haritha, “Comparison of MPPT algorithms for dc-dc converters based PV systems”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, PP. 18-23, 2012.
12. S.Brunton, C.Rowley, S.Kulkani , C.Clarkson, ”Maximum power point tracking for photovoltaic optimization using ripple-based extremum seeking control”, IEEE transactions on power electronics, PP. 1-20, 2010.

AUTHOR PROFILE

Mr. Ahmed Yahfdhou [yahevdhouah@yahoo.fr] was born in Elb-adress, Mauritania, in 1978. He received his Master degree in Solar Energy, Materials and Systems from College of Sciences and Technics, Dakar, Senegal, Cheikh Anta DIOP University in the year 2010. He is working on his doctorate thesis at Cheikh Anta DIOP University Dakar, Senegal. The interest of his research is about the field of Renewable Energy and Semiconductor devices characterization.

Prof. Abel Kader Mahmoud [mkader@univ-nkc.mr] was born in Mauritania. He received his Doctorate degree in 2009 in Solar Energy from FST, Dakar, Cheikh Anta Diop University. He is working as prof, in the Physics department of Nouakchott University, Mauritania. He is also the director of the Applied Center of Renewable Energy in Mauritania. His research interest in the field of Renewable Energy, Electrical Engineering and reverse osmosis.

Prof. Issakha Youm [iyoum2@yahoo.fr] was born in Ngaparou, Senegal. His received his Doctorate degree in 1991 in Solar Energy from FST, Dakar, Cheikh Anta DIOP University. He is working as Prof. in the Physics Department of Cheikh Anta DIOP University Dakar, Senegal. He is also the director of the Center of the Study and Research of the Renewable Energy, Senegal. His research interest is in the field of Renewable Energy and Semiconductor devices characterization

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)