A Variable Incremental Conductance MPPT Algorithm Applied to Photovoltaic Water Pumping System

S. Abdourraziq, R. El Bachtiri

Abstract—The use of solar energy as a source for pumping water is one of the promising areas in the photovoltaic (PV) application. The energy of photovoltaic pumping systems (PVPS) can be widely improved by employing an MPPT algorithm. This will lead consequently to maximize the electrical motor speed of the system. This paper presents a modified incremental conductance (IncCond) MPPT algorithm with direct control method applied to a standalone PV pumping system. The influence of the algorithm parameters on system behavior is investigated and compared with the traditional (INC) method. The studied system consists of a PV panel, a DC-DC boost converter, and a PMDC motor-pump. The simulation of the system by MATLAB-SIMULINK is carried out. Simulation results found are satisfactory.

Keywords—Photovoltaic pumping system (PVPS), incremental conductance (INC), MPPT algorithm, boost converter.

I. INTRODUCTION

A standalone photovoltaic pumping system (PVPS) has become one of the most promising fields in photovoltaic applications, specifically in the remote areas, that have an important insulation and have no access to an electric grid. The photovoltaic pumping system has become one of the most promising areas for photovoltaic applications. To improve the efficiency of the system and to exploit a maximum energy of the PV panel, we use the technique of search of the maximum power point (MPP). Several papers has studied a directly connected of the PV array and the motor-pump set in the PV pumping system[1], the intersection point of the voltage-current curve and curve of motor-pump can be far from the (MPP) which decrease an important proportion of the available solar power. An adapter DC-DC boost converter controlled by a MPPT algorithm can be used between the PV generator and motor-pump.

In the literature, several maximum power point tracking (MPPT) algorithms have been proposed including fractional open circuit voltage [1], perturb and observe (P&O) [2], [3], incremental conductance (IncCond) [4]-[6], a neural network method [7], and a fuzzy logic control (FLC) method [8], [9].

The incremental-conductance (IncCond) method [10] commonly used a fixed iteration step size to track the MPP; the step size is determined by the requirements of the accuracy at steady state and the response speed of the MPPT. The MPP

is reached when the slope of the PV array power curve versus voltage is zero. Thus, the accuracy and the speed of response time are highly depended on the fixed step size defined: if the step size of tracking is small, the accuracy is high and the speed response is so slow, however the situation is reversed with a larger step size [4], which influence in the power drive of the load (motor-pump) . To overcome this problem, a novel improved variable step-size INC algorithm with direct control is proposed [5]. In this paper we propose a study of the performance of the variable step size INC algorithm for standalone PV pumping systems, the influence of the proposed algorithm on system behavior is depicted, and the different advantages are identified. The proposed method was tested in MATLAB/SIMULINK environment; the obtained results indicate the feasibility and improved functionality of the system.

The studied system consists of the PV array, the DC-DC boost converter, and the DC motor-pump. The block diagram of the PV pumping system studied is shown in Fig. 1.
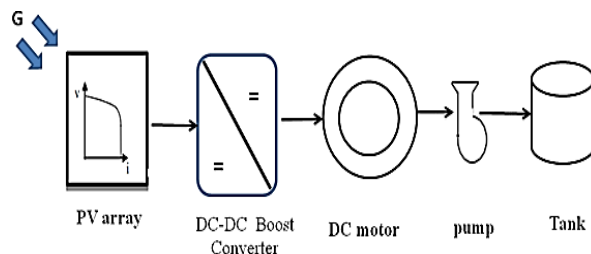

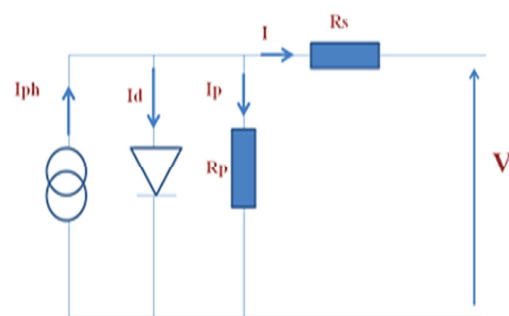Fig. 1 General configuration of a photovoltaic pumping system

Fig. 2 Equivalent circuit of a PV cell

S. Abdourraziq and R. El Bachtiri are with the Sidi Mohammed Ben Abdellah University, LESSI Lab FSDM, REEPER Group, EST, Fez, Morocco (phone: +212 6 18 049680; e-mail: sarah.abdourraziq@usmba.ac.ma, rachdi.elbachtiri@usmba.ac.ma).

II. PV PANEL MODEL

PV array is a p-n junction semiconductor, which converts light into electricity. In the literature, there are several mathematical models which describe the I − V characteristic [11], [12]. The difference between these models is the procedure of the calculation, the intervening parameters number to compute the I –V characteristic and results accuracy. The equivalent circuit of a PV module is shown in Fig. 2. Based on this circuit model, the behavior of the PV array may be described by:
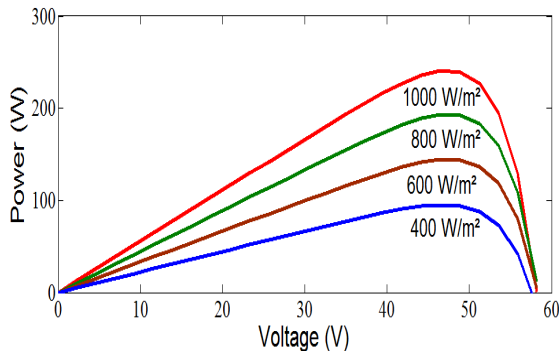
$$I = I_{ph} - I_d - I_p \qquad (1)$$

$$I_d = I_o(\exp(\frac{V_j \cdot q}{K_o \cdot T})) - 1) \qquad (2)$$
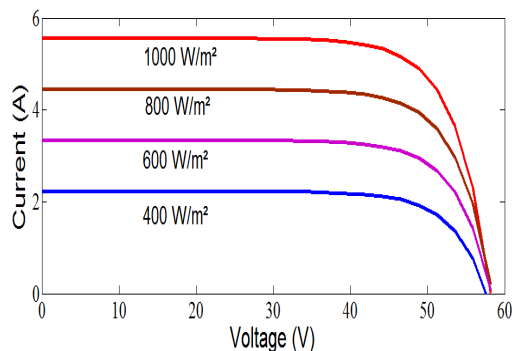
$$I_p = \frac{V + R_s \cdot I}{R_p} \qquad (3)$$

$$I = I_{ph} - I_o(\exp\left(\frac{V_j q}{K_o T}\right) - 1) - \frac{V + R_s \cdot I}{R_p} \qquad (4)$$

where V is the PV output voltage, I is the PV output current, I_{ph} is the photocurrent, I_0 is the saturation current, Rs is the series resistance, Rp is the shunt resistance, and q is the electronic charge, n is the diode factor, K is the Boltzmann's constant, T is the junction temperature.

(a)

(b)

Fig. 3 Output characteristics of PV array (a) V-P, (b) V-P

The output I-V and P-V curves results of the simulation of the PV cell for different values of radiation are presented in Figs. 3 (a) and (b).

III. FIXED STEP SIZE INCREMENTAL CONDUCTANCE ALGORITHM

Incremental conductance method is the most appropriate MPPT algorithm [5], [6]; once the speed and tracking accuracy are combined. It is based on the fact that the slop of the power-voltage curve of a PV generator is equal to zero at MPP.

From the measurements of voltage V and current I, the algorithm calculates the output P and its derivative as a function of voltage dP/dV. It uses the derivative of the power-voltage output characteristic to decide if the duty cycle ratio must be increased or decreased. The general flowchart of the fixed step size IncCond algorithm is shown in Fig. 4.

The corresponding PV output power is:

$$P = V \cdot I$$

$$dP = V \cdot dI + I.dV$$

The dP / dV ratio can be expressed as:

$$\frac{dP}{dV} = \frac{I}{V} + \frac{dI}{dV}$$

At the maximum power point (MPP), the equation becomes:

$$\frac{dI}{dV} = -\frac{I}{V}$$

$$\begin{cases} \Delta V/\Delta I = -V/I, \text{ at MPP} \\ \Delta V/\Delta I > -V/I, \text{ left of MPP} \\ \Delta V/\Delta I < -V/I, \text{ right of MPP.} \end{cases}$$

The drawback of the IncCond method with fixed step size is: if we use a large step size, the search of the MPP is faster, else we have an excessive steady state oscillation, which result a low efficiency [13]-[15]. This situation is reversed when the MPPT is running with a smaller step size. To solve this problem, a several novel variable step-size IncCond algorithm are presented in the literature [16], [17]. In this paper we presented a modified step size IncCond method with direct control (without proportional integral control loop) [18] applied on a standalone PV pumping system to improve its functioning. The principle design of the variable step-size with direct control is developed on the uniform insulation for the PV pumping system. Different simulation results are provided, its shows that the proposed method can greatly improve the dynamic performance of the PV output power and accuracy of the output motor speed.
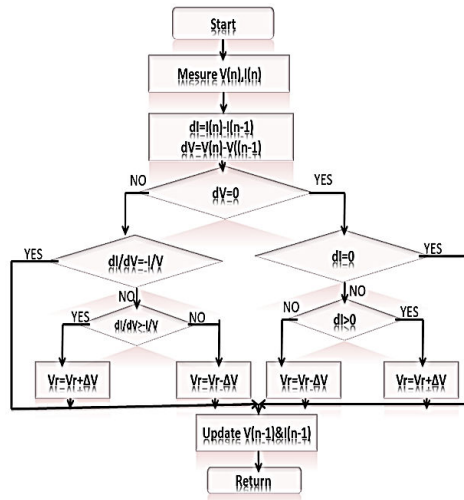
Fig. 4 Flowchart of traditional IncCond MPPT algorithm

IV. PROPOSED MPPT INCREMENTAL CONDUCTANCE ALGORITHM

The proposed IncCond method operates with a variable step size, where the duty cycle is adjusted directly. Note that V (k) and I (k) are the PV array output voltage and current at time k. The iterations of the novel step size are given by following:

$$D(k) = D(k-1) \pm N * \frac{|dP|}{|dV|} = D(k-1) \pm N * \frac{|P(k) - P(k-1)|}{|V(k) - V(k-1)|}$$

where: N: the scaling factor for adjusting the step size. D(k): the duty cycle at the (k) the sample of time.

When the operating point is far from the MPP, the step-size ΔD becomes large, in this case the algorithm tends to MPP faster, and when the operating point is near to the MPP the step-size becomes small to close the MPP. The flowchart of the modified variable step size INC MPPT algorithm is shown in Fig. 5.
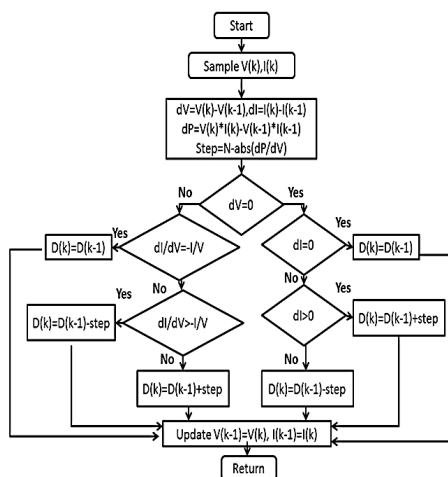

Fig. 5 Flowchart of the modified variable step size INC MPPT algorithm

V. SIMULATION

The Simulink model of variable incremental conductance MPPT is shown in Figs 6-8. The simulation has been carried out at irradiance and temperature level of 1000W/m2, 25°C, respectively. Simulaton is carried out on a motor-pump load.

Figs. 6-8 show the output power, current and voltage of PV panel with traditional IncCond method and proposed method.
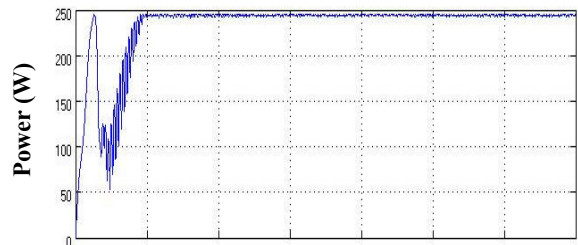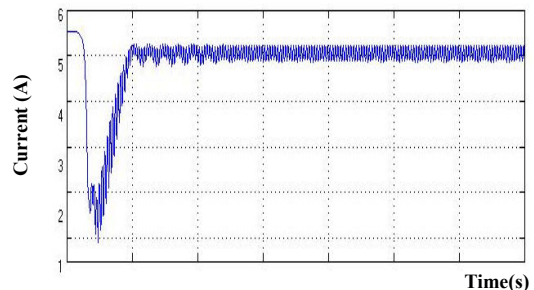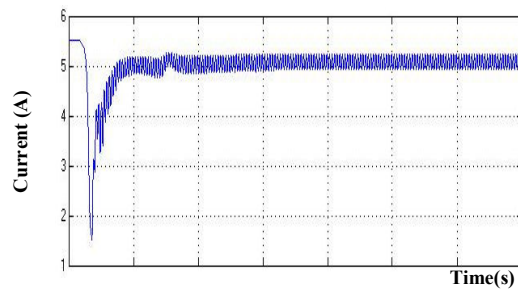

(a)
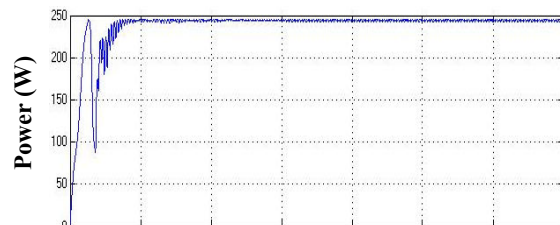
(b)

Fig. 6 Output characteristic of power (a) fixed step-size IncCond method and (b) variable step-size IncCond method
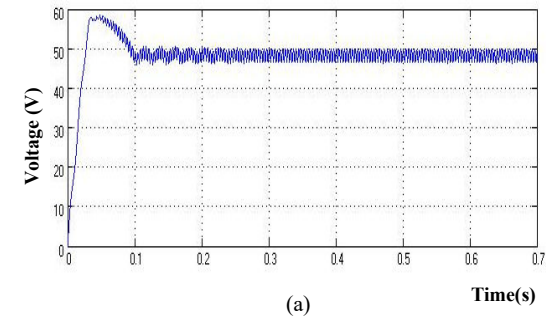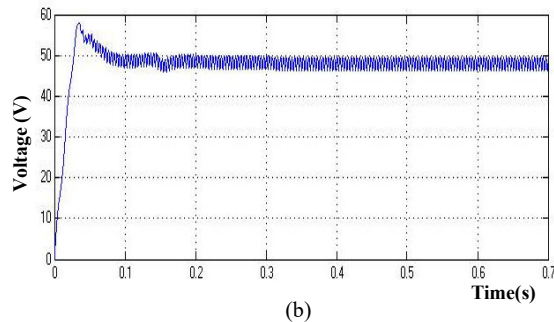

(a)

(b)

Fig. 7 Output characteristic of current with (a) fixed step-size IncCond method and (b) variable step-size IncCond method
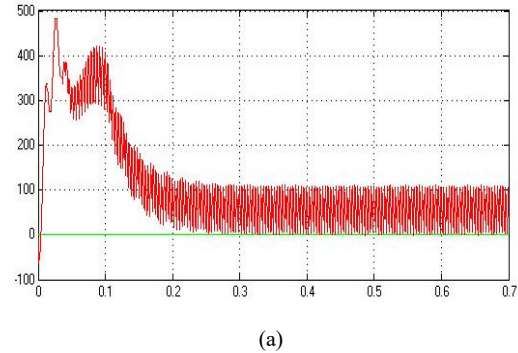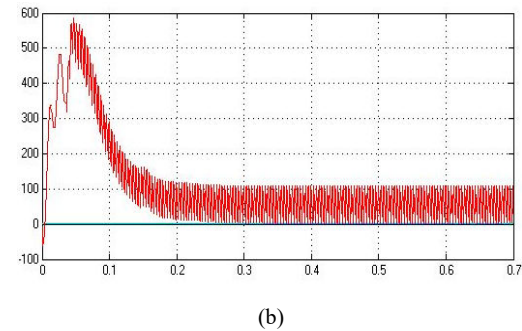
(a)

(b)

Fig. 8 Output characteristic of voltage (a) fixed step-size IncCond method and (b) variable step-size IncCond method
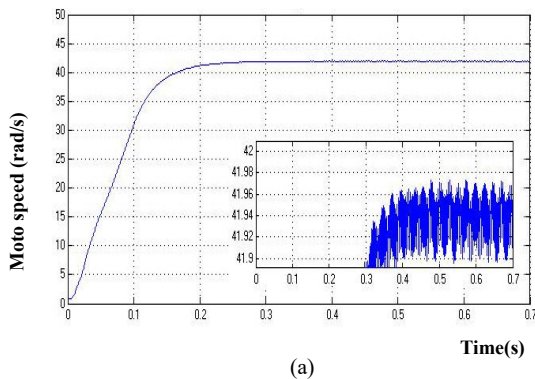

(a)
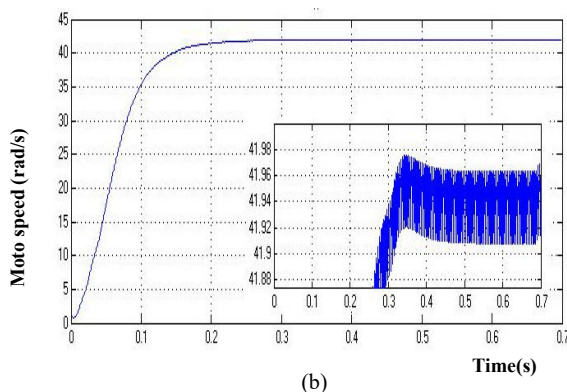

(b)

Fig. 9 Output characteristic motor speed (a) traditional IncCond method (b) proposed IncCond method

(a)

(b)

Fig. 10 Output characteristic motor torque (a) traditional IncCond method (b) proposed IncCond method

Figs. 9 and 10 show the output characteristics of the motor. They present clearly the efficiency of the proposed technique compared to traditional one.

VI. CONCLUSION

Results presented in the paper clearly demonstrate how the proposed IncCond algorithm is less confused by noise and system dynamics. The main concluding remarks are summarized as follows:

- The obtained simulation results have shown the good performance of the proposed controller in terms of accuracy and speed of response time for the output power of the PV generator,
- The accuracy of the motor speed is improved which influence in the effectiveness of the drive system,
- It is shown also via this paper, that the accuracy and the value of the electrical torque are widely increased.

REFERENCES

[1] Abdourraziq Sarah, El Bachtiri Rachid, Modeling of aphotovoltaic pumping system using centrifugal pump and DC motor, Sustainability in Energy and Buildings: Research Advances, Mediterranean Green Energy Forum 2013 (MGEF-13) : Vol.2 : pp.1-6 : mgf13s-002.
[2] Moussi, A. Torki, An improved efficiency permanent magnet brushless DC motor PV pumping system, *LARHYSS* Journal, N°.01, Mai 2002
[3] Mohamed Amine Abdourraziq, Mohamed Oussaid, Mohamed Maaroufi, Sarah Abdourraziq, "Modifies P&O MPPT Technique for Photovoltaic System," International Conference on Renewable Energy Research and Applications, ICRERA 2013, pp 728-733.
[4] Sarah, A.; Rachid, E.B., A perturb and observe method using fuzzy logic control for PV pumping system, IEEE Multimedia Computing and Systems (ICMCS'14), pp 1608-1612.

[5] Sarah Abdourraziq, Rachid El Bachtiri, "A Novel MPPT Dual Fuzzy Logic Applied To Resistive Load and PV Pumping System", International Review of Automatic Control (IREACO), Vol 7, No 4 (2014), pp 446-452.

[6] Sarah Abdourraziq, Rachid El Bachtiri, A Perturb and Observe Method using Dual Fuzzy Logic Control for Resistive Load, Recent Advances in Environmental Science and Biomedicine, ISBN: 978-960-474-391-9,pp 107- 112.

[7] Sreekanth.S, Jacob Raglend, A Comparative and Analytical Study of Various Incremental Algorithms Applied in Solar Cell, 2012 International Conference on Computing, Electronics and Electrical Technologies (ICCEET), 2012 IEEE pp 452- 456.

[8] Mohammed Ali Elgendy, Bashar Zahawi, Comparison of Directly Connected and Constant Voltage Controlled Photovoltaic Pumping Systems, IEEE Transactions on Sustainable Energy, Vol. 1, No. 3, October 2010.

[9] Mohammed A. Elgendy, Bashar Zahawi, Assessment of Perturb and Observe MPPT Algorithm Implementation Techniques for PV Pumping Applications, IEEE Transactions on Sustainable Energy, Vol. 3, No. 1, January 2012.

[10] Bidyadhar Subudhi, Raseswari Pradhan, A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems, IEEE Transactions on Sustainable Energy, Vol. 4, No. 1, January 2013.

[11] Mohammed A. Elgendy, Bashar Zahawi, Assessment of the Incremental Conductance Maximum Power Point Tracking Algorithm, IEEE Transactions on Sustainable Energy, Vol. 4, No. 1, January 2013.

[12] Himanshu Kumar, R.K. Tripathi, Simulation of Variable Incremental Conductance Method with Direct Control Method Using Boost Converter, 978-1-4673-0455-9/12/2012 IEEE.

[13] Qiang Mei, Mingwei Shan, A Novel Improved Variable Step-Size Incremental-Resistance MPPT Method for PV Systems, IEEE Transactions on Industrial Electronics, Vol. 58, No. 6, June 2011.

[14] Hiyama, T., S. Kouzuma, and T. Imakubo, Identification of optimal operating point of PV modules using neural network for real time maximum power tracking control. Energy Conversion, IEEE Transactions on, 1995. 10(2): p. 360-367.

[15] Bader N. Alajmi, Khaled H. Ahmed, A Maximum Power Point Tracking Technique for Partially Shaded Photovoltaic Systems in Microgrids, IEEE Transactions on Industrial Electronics, Vol. 60, No. 4, April 2013.

[16] Yufeng Hu, Jun Liu, A MPPT Control Method of PV System Based on Fuzzy Logic and Particle Swarm Optimization, IEEE Transactions ON Industrial Electronics, Vol. 58, NO. 6, June 2011.

[17] Emad M. Ahmed, Masahito Shoyama, Stability Study of Variable Step Size Incremental Conductance/Impedance MPPT for PV systems, 8th International Conference on Power Electronics - ECCE Asia May 30- June 3, 2011.

[18] Badia Amrouche, Abderrezak Guessoum, A simple behavioural model for solar module electric characteristics based on the first order system step response for MPPT study and comparison, Applied Energy 91 (2012) 395–404.