Improved Variable Step Size P&O MPPT Algorithm for PV Systems

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Abstract— **Algorithms for the maximum power point tracking MPP (Maximum Power Point), seek to maximize the delivered power of a photovoltaic panel. The Perturb and Observe (P&O) algorithm is the more used due to simplicity, however it is not the most efficient due to the perturbation step is fixed, at higher the size step fastest the MPP will be reached, but there would be a high steady state error; if the size step is low there would be less steady state error, but the MPP tracking became slow. Other well know method is the algorithm of Conductance Incremental (IC), in this method the step depends of the power variation versus the voltage. The variable step for P&O is more efficient for short atmospheric variations with less oscillations in the tracking and the variable step for CI is more efficient for big atmospheric variations with a fast MPP tracking. In this paper the 2 methods are combine to reduce oscillations and for a fast tracking for big and short irradiance variations.**

Index Terms-- **Maximum Power Point (MPP), Maximum Power Point Tracking (MPPT), Incremental Conductance (IC), Perturb and Observed (P&O), Photovoltaic Systems (PV), Variable step size.**

I. INTRODUCTION

The renewable energies in the 21st century have provided a form of obtaining electric energy around the world. We may emphasize the photovoltaic solar energy. This type of energy is consider one of the most economic and friendly with the environment.

Globally, with the increase of the demand for electricity, the developed countries have been in the need to make changes in their energy matrix, with the search for new ways to generate energy without any environment impact using renewable sources. Actually, is currently studying how to integrate the renewable energy sources into the conventional electrical systems [1].

The advantages of the PV energy compared to other types of renewable energy such as the wind energy for example are the facility of implementation, accessible costs, the absence of noise of moving mechanic parts and the low maintenance needed. However the efficiency of the photovoltaic solar panel is between 12% and 20% and can change depending of irradiance and temperature conditions and the used load, to meet the required demand is needed to increase the number of photovoltaic panels increasing the cost and viability of the system [2].

To improve the efficiency of the photovoltaic panels, many methods have been developed, the more common and used are, the P&O [3], IC [4], Fuzzy Logic [5] and Neural Networks [6]. Each one of this methods uses a different algorithm to perform the tracking being the P&O the more used due to the simplicity and efficiency. This paper expose the design and implementation of a maximum power point tracking system for solar panel based on the algorithm of P&O.

The next section shows a brief description of the equivalent model of a photovoltaic solar cell and the implementation system; in the third section are describe the Variable Step P&O and IC algorithm; in the fourth section will describe the proposed algorithm. This paper end with the experimental results and comparing the different studied methods.

II. MODELING OF SOLAR PV MODULE

A. Solar cell model

A solar cell can be represented as the circuit in figure 1, with a current source, a diode and a resistance [10].

The I_L current generated by the source depends of the irradiance G $[W/m^2]$ and the temperature, (1) describe the output current I for a photovoltaic solar cell.

$$I = I_L - I_O\left(e \wedge \left(\frac{V+IR_S}{A}\right) - 1\right) \qquad (1)$$

Figure 2 shows the output power of Simax SM 536-9 solar panel in function of the voltage V with different irradiance values and a temperature of 25C°; for G=1000 W/m^2 the MPP value is 90W, for G=550 W/m^2 the MPP values is 50W and for para G=300 W/m^2 the MPP value is 28W.

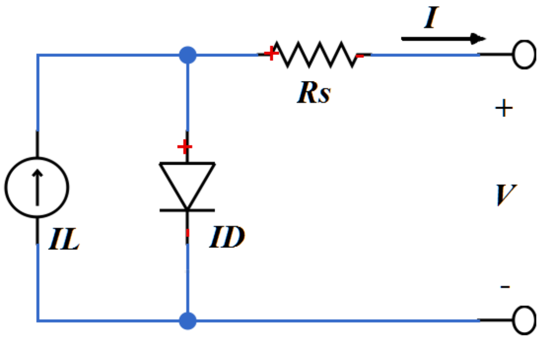

Figure 1. Equivalent circuit of a PV solar cell.

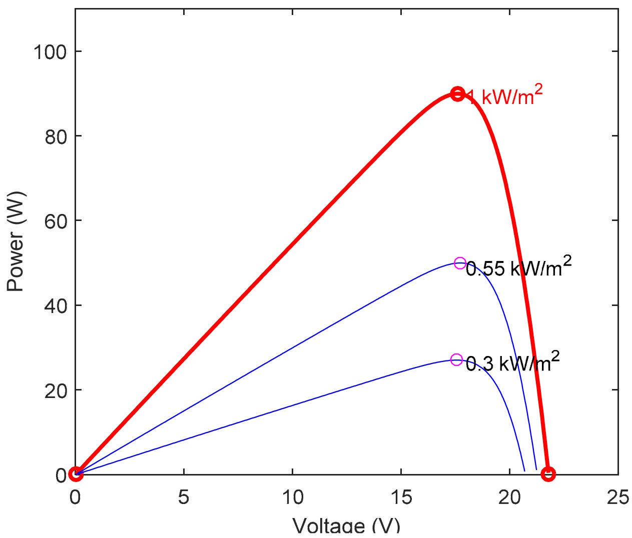

Figure 2. Power delivered by the Simax SM 536-9 solar panel with irradiance variation.

B. *Boost Converter*

The converter used for the testing is a Boost-Converter as is show in the figure 3; the output voltage is higher than the input voltage according with (2).

$$V_0 = \frac{V_i}{1-D} \qquad (2)$$

Where:

V_0 : Converter Output Voltage

V_i : Converter Input Voltage

D: PWM Duty Cycle

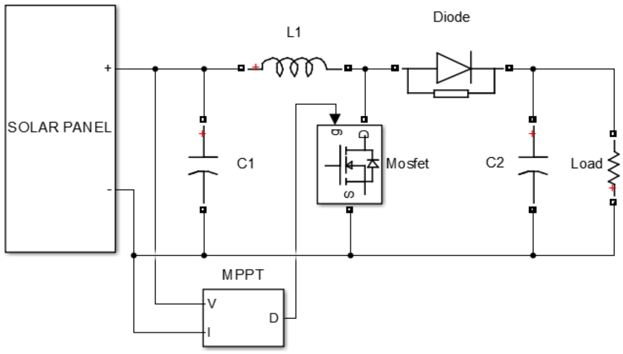

Figure 3. MPPT System with Boost Converter.

The inductance, capacitance and frequency values are shown in the table 1.

TABLE 1. PARAMETERS OF THE BOOST CONVERTER

Element	Value
L1	1 mH
C1	100 uF
C2	1000 uF
F	30 KHz
LOAD	50 Ω

The algorithm of maximum power point tracking (MPPT) measure the instant values of voltage and current and adjust the PWM duty cycle through the tracking MPP algorithm of P&O until the converter pull out the maximum power of the solar panel.

III. MPPT VARIABLE STEP SIZE ALGORITHMS

A. *Variable step size P&O algorithm*

The fixed step size P&O algorithm begin with the obtaining of the instantaneous values of voltage and current to the output panel, and perturb the operation voltage, then calculate the instantaneous power and compare with the previous power. After this the operating voltage increase or decrease depending of the duty cycle *D* until the MPP is reached [2]. If the step size is short there will be more steady state error and converge time became slow, while if the size step is big, converge time became fast but there will be more steady state error. To solve this problem the variable step size P&O algorithm has been developed [9] [10].

The flowchart of the variable step size P&O algorithm [11], is shown in the figure 4 the size step is calculated with (3):

$$D(k) = D(k-1) \pm N \times \Delta P \qquad (3)$$

Where *D(k)* is the actual value of duty cycle, *D(k-1)* is the previous value of duty cycle, *N* is the stepping factor and ΔP is the power variation against irradiance changes.

The step size is automatically adjusts against irradiance changes. Short irradiance changes produces short changes in the ΔP value and a short step size, meanwhile big irradiance changes produces big changes in the ΔP value and a big step size.

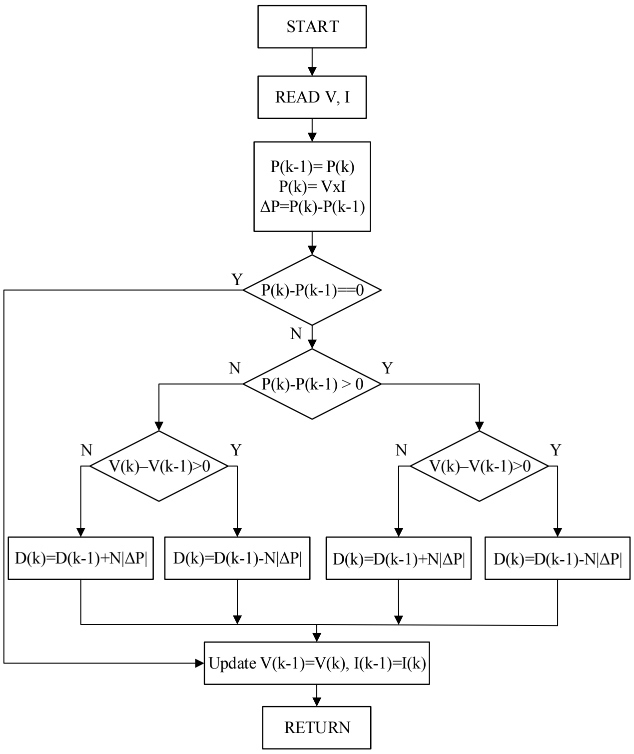

Figure 4. Variable step size P&O algorithm.

B. *Variable step size IC algorithm.*

The IC algorithm follows of the slope of the P-V curve. In the MPP it is zero (4), in the right side the MPP the slope is negative (5) and in the left side the slope is positive (6) [12].

$$dP/dV = 0 \quad \text{at MPP} \tag{4}$$

$$dP/dV > 0 \quad \text{left of MPP} \tag{5}$$

$$dP/dV < 0 \quad \text{right of MPP} \tag{6}$$

To improve the response times and the steady state error the variable step size IC algorithm has been developed. The flowchart of the algorithm [13] is shown in the figure 5. The step size is calculated in function of the variation of power and the variation of voltage as is show in (7)-(10):

$$D(k) = D(k-1) \pm N \times \frac{|\Delta P|}{|\Delta V|} \tag{7}$$

$$\Delta P = P(k) - P(k-1) \tag{8}$$

$$\Delta V = V(k) - V(k-1) \tag{9}$$

$$D(k) = D(k-1) \pm N \times \frac{|P(k)-P(k-1)|}{|V(k)-V(k-1)|} \tag{10}$$

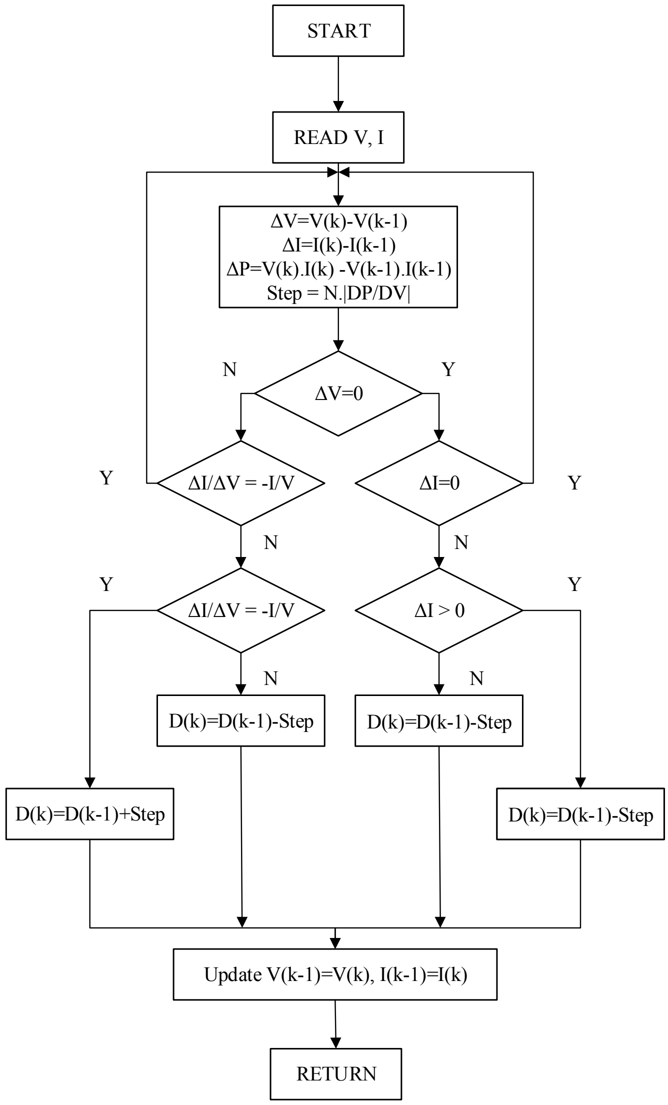

Figure 5. IC Variable step size algorithm

IV. VARIABLE STEP IMPROVED ALGORITHM

The variable step size improved algorithm uses the P&O algorithm for the MPP tracking and the step size is a combination of P&O and IC Algorithms, described in the third section.

The variable step size P&O algorithm is more efficient for short irradiance changes. But the tracking is slow for big irradiance changes comparing to the variable step size CI algorithm. For short irradiance changes the variable step size IC algorithm is less efficient due to if the value of ΔV is near to zero, the size step tends to the infinite, this cause that the operation point displace far from the MPP. For short irradiance changes, the step size is calculated with (3), when there are bigger irradiance variations the step size is calculated with (10).

The flow diagram is show in the figure 6. If the power variation ΔP is higher than a certain value M the size step will be $N \times \Delta P/\Delta V$, if the power variation is less than M the size step will be $N \times \Delta P$. M is the value of maximum power for considering that a short change in irradiance has occurred.

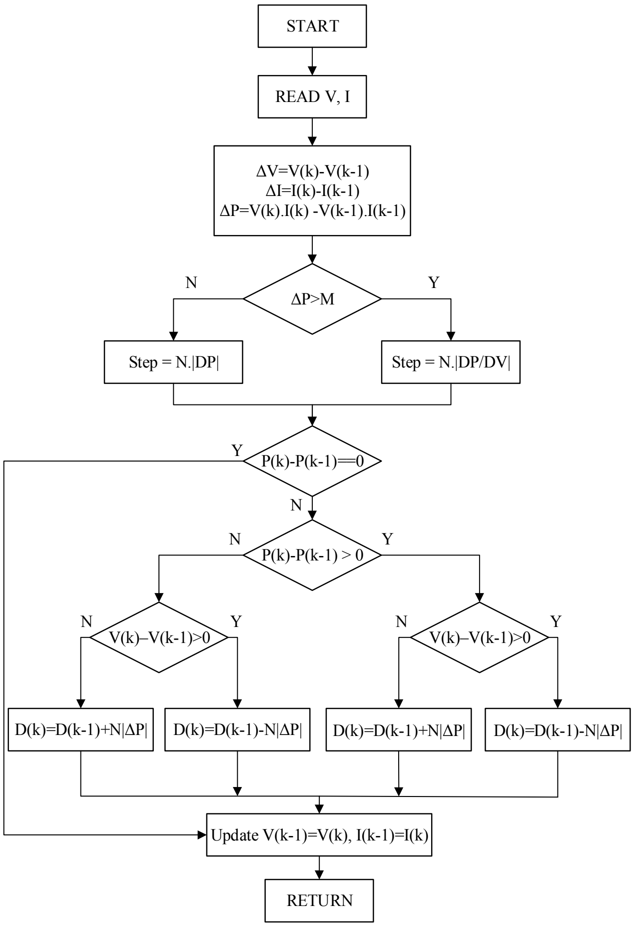

Figure 6. Improved variable step size algorithm

V. Experimental Results

Tests were performed using the Boost-converter of the figure 3 with the values of the table 1 and a solar panel SIMAX SM536-9 whose parameter are shown in the table 2. The values of maximum power for different values of irradiance are shown in the figure 2.

TABLE 2. CHARACTERISTICS OF SIMAX SM536-9 [15]

PARAMETERS	VALUES
$P_{MPP\ STC}$	90 W
$V_{MPP\ STC}$	17.6 V
$I_{MPP\ STC}$	5.11 A
$V_{OC\ STC}$	21.8 V
$I_{SC\ STC}$	5.51 A
Power Coefficient α_k	-0.45 %/K
Voltage Coefficient β_k	0.35 %/K
Current Coefficient φ_k	0.065 %/K
N	36

The figures 7 and 8 show the power delivered by the solar panel with an irradiance decrease from 550 W/m^2 to 430 W/m^2 and a constant temperature of 25C°. It can be observed that the variable step size P&O algorithm make a fast tracking of the MPP of 200ms approximately, while the variable step size IC algorithm takes 600ms approximately to reach de MPP and produce a loss of power near to 20W, so for short irradiance changes the variable step size P&O algorithm is more effective than the IC algorithm.

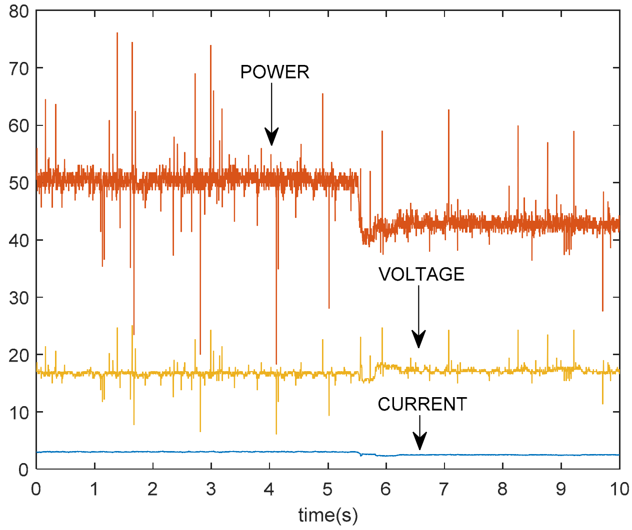

Figure 7. Output power of the solar panel with irradiance decrease using variable step size P&O algorithm.

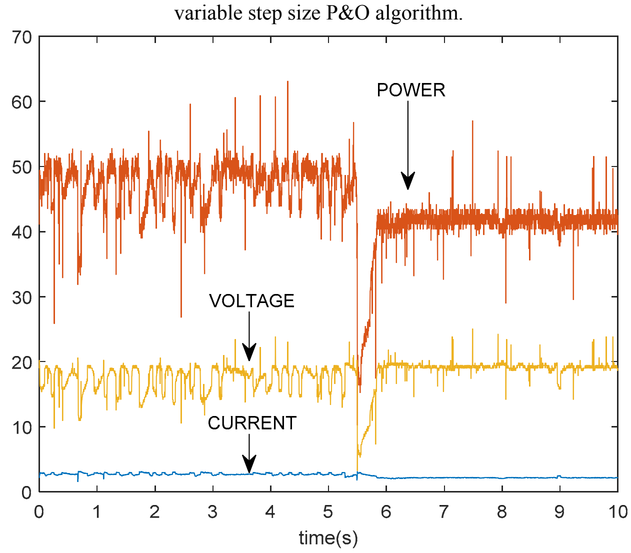

Figure 8. Output power of the solar panel with irradiance decrease using variable step size IC algorithm.

The figures 9 and 10 show the delivered power by solar panel with irradiance decrease from 550 W/m^2 to 300 $W/m^2$with a constant temperature of 25 C°. It can be observed that the variable step size P&O algorithm makes the MPP tracking approximately in 1400ms that is bigger than the 600ms of the IC algorithm. Also the algorithm of variable step of P&O produce a decrease of power of 10 W before reaching the MPP.

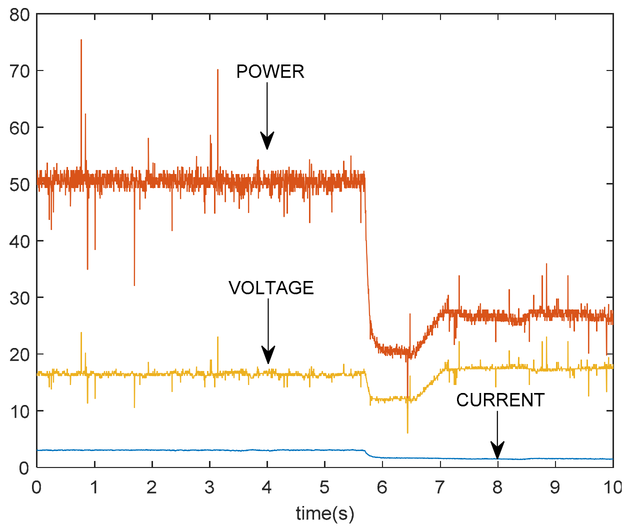

Figure 9. Output power of the solar panel with irradiance decrease using variable step size P&O algorithm.

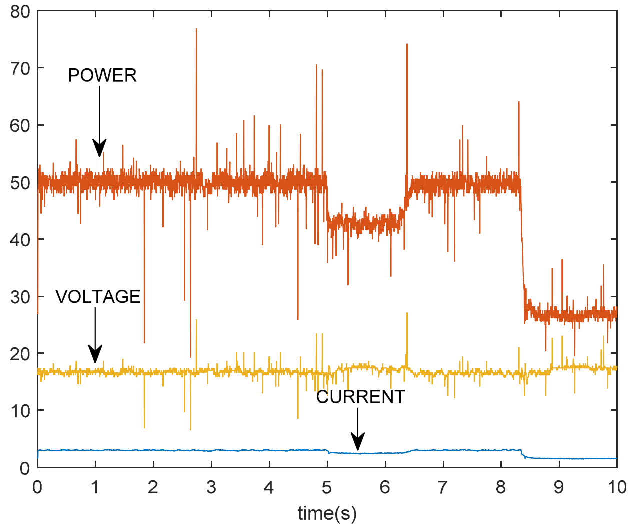

Figure 11. Output power of the solar panel with irradiance changes using the improved variable step size algorithm.

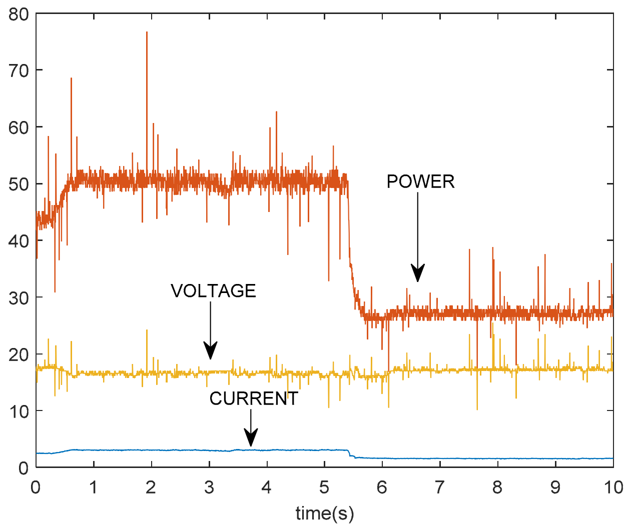

Figure 10. Output power of the solar panel with irradiance decrease using variable step size IC algorithm.

Figure 11 show the delivered power by the solar panel with the improved variable step size algorithm for small and big irradiance changes.

When the irradiance decrease from 550 W/m^2 to 430 W/m^2, the step size is calculated in function of *ΔP*, avoiding the power decrease when *ΔP/ΔV* be used.

When the irradiance decrease from 550 W/m^2 to 300 W/m^2, the step size is calculated in function of *ΔP/ΔV*, improving the response time when *ΔP* was used.

Tables 3 and 4 show the response time of the evaluated variable step size algorithms and the power decrease for irradiance changes.

TABLE 3. COMPARATIVE TABLE OF VARIABLE STEP SIZE MPPT METHODS WITH IRRADIANCE REDUCTION OF FROM 550 W/m^2 TO 430 W/m^2

MPPT Method	Response Time	Power Decrease
P&O	200 ms	0 W
CI	600 ms	20 W
Improved Algorithm	200 ms	0 W

TABLE 4. COMPARATIVE TABLE OF VARIABLE STEP SIZE MPPT METHODS WITH IRRADIANCE REDUCTION OF FROM 550 W/m^2 TO 300 W/m^2

MPPT Method	Response Time	Power Decrease
P&O	1600 ms	10 W
CI	200 ms	0 W
Improved Algorithm	200 ms	0 W

VI. CONCLUSIONS

This paper propose a variable step size algorithm using the P&O and IC methods, the results are obtained from the implementation of the MPPT System.

Among all the studied methods, the improved variable step size algorithm has lower response time and do not exist power decrease before reaching the MPP comparing to the other methods.

It is concluded that, to prevent the power decrease and get better response time the improved variable step size algorithm achieves higher efficiency than the P&O and IC algorithms.

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