Contribution to Perturb and Observe Algorithm to Maximum Power Point Tracker for Photovoltaic Systems

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ABSTRACT: Traditionally, for the photovoltaic module work around its maximum output power is used a Maximum Power Point Tracking (MPPT). The MPPT is extremely important in photovoltaic systems its correct performance allows the best use of electrical power. Therefor the MPPT is an essential part of a photovoltaic system. In the most case the MPPT algorithm modify the duty cycle for switching converter, searching the point when its delivery more power. This paper proposed a new method for MPPT called Delta P (ΔP), based a traditional method Perturbation and Observation (P&O). The technique purpose increasing the time of searching in transitional, reducing the error on permanent regime. Furthermore this will increasing the system efficiency without used new Input parameters. The performance of proposed technique was assessed with simulations and good results were obtained.

Keywords *MPPT, photovoltaic system, P&O.*

1. INTRODUCTION

With the unbridled increase in the demand for energy on a worldwide scale, and due to the scarcity of available reserves, an intense search for alternative energy sources has been prompted in the last decade. According to the International Energy Agency (IEA, 2012), a 30% increase in the global demand for energy, is expected by 2035. This scenario has stimulated a marked surge in the development of technologies applied to renewable energy sources, prioritizing efficiency, reliability and cost reduction.

The growing demand for wind and solar energy has put them in the prime position as renewable sources, and as indispensable components of the global energy matrix. According to the IEA (2012), in 2035 renewable sources will represent one third of the worldwide production, in which solar energy is the fastest growing source.

Efforts to develop national technologies in photovoltaic microgeneration – the next energy revolution in the world, according to the IEA – will prevent the country from having to import almost one hundred percent of the technologies from pioneering countries, which is currently the case with systems based on aerogenerators.

In photovoltaic systems, the Maximum Power Point Tracker (MPPT) is done by a control technique that operates directly on the duty cycle of the power switch of the converter seeking the greatest power transfer possible for photovoltaic arrangement, which have voltage and current values that vary, mainly in relation to the irradiance and temperatures of the cells.

Based on the Pertubation and Observation (P&O) alogorithm method of control, MARTINS & COELHO & SANTOS (2011), and a variation of this, the Delta P (ΔP) algorithm, demonstrated better performance, being faster and more accurate in both degree type and linear variations. The tests were carried out by PSIM® simulation software, with a Boost type power converter linked to an Direct Current (DC) bus and a 200 W solar panel fed by varying temperatures and irradiances.

2. MAXIMUM POWER POINT TRACKING

Maximum power point tracking is a control method that will be performed directly on the power bus of the Boost, seeking out the greatest power transfer possible of the photovoltaic panel through the variation of the relation between voltage and current, according to the power curve as seen in Figure 1. This curve varies mainly in detriment to the irradiance issued in the panel and to its temperature.

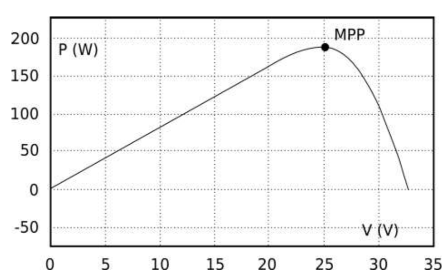

Figure 1. Power characteristic curve of a photovoltaic panel.

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The voltage (where V_i is the input voltage and V_0 is the output voltage) and, consequently, the current depends on the duty cycle (D), by the equation (1); from the adjustment of this cycle it will be possible to reach the maximum power point of the panel, once the output voltage is fixed at 48 V, assured by the DC bus.

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

3. PERTURBATION AND OBSERVATION ALGORITHM

Among the diverse methods that exist for determining the maximum power point used in phtovoltaic panels, the P&O method stands out for its efficiency and the simplicity of implementation, shown in a simplified model version in Figure 2. In region "A" of Figure 2, the algorithm updates the duty cycle and in region "B" a verification is done, if it is within the stipulated limits.

This method of control uses only measures of photovoltaic panel voltage and current as input parameters, which can be done at the input of the converter itself (preventing the need for external sensors), and has a low computational cost and converges for the maximum power with tracking that has a low error rate.

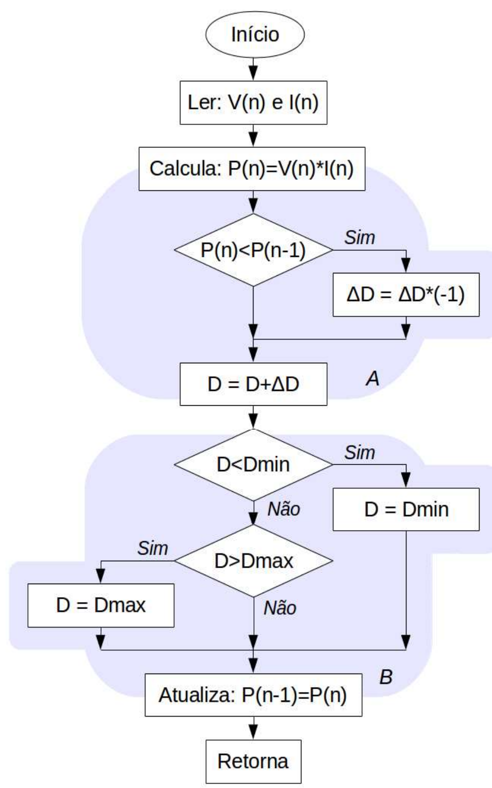

Figure 2. P&O algorithm.

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4. ALGORITHM DELTA P

The ΔP algorithm is a contribution that seeks to increase the velocity of tracking in the transient, while reducing errors in the permanent regime presented by the P&O algorithm without the need for new input parameters nor compromising its low computational cost.

In the ΔP algorithm, Figure 3, the increase of the duty cycle will depend on the derivation of the power variation. The greater the power variation, the greater the increase or decrease of the work cycle – a proportionality that makes the algorithm run faster in the curve seeking the highest point and having variations that tend to zero in the permanent regime, this operation being simplified by the comparison between the present and former power through a constant. In Figure 3, similar to algorithm P&O, we have the updating of the duty cycle in region "A", and the verification of the limits in region "B".

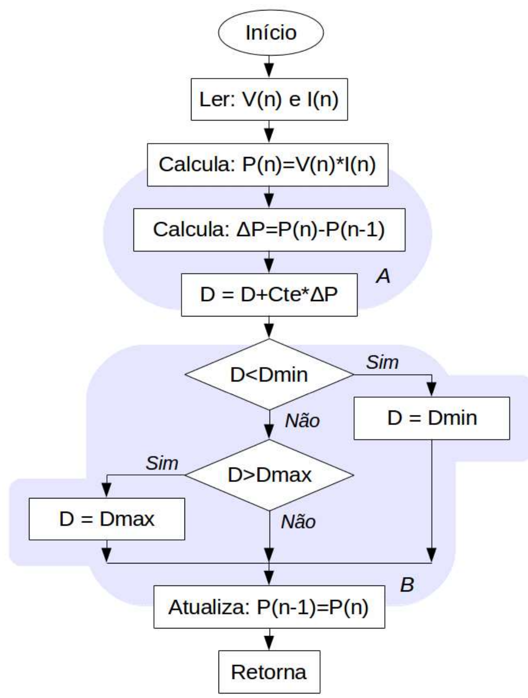

Figure 3. ΔP algorithm.

5. SIMULATION METHODOLOGY

The simulation is comprised of a photovoltaic panel linked to a Boost converter that is fed by a 48 V DC bus. This converter has its switching controlled by a block with the MPPT algorithm written in C language. In Figure 4 the diagram of the block system is shown.

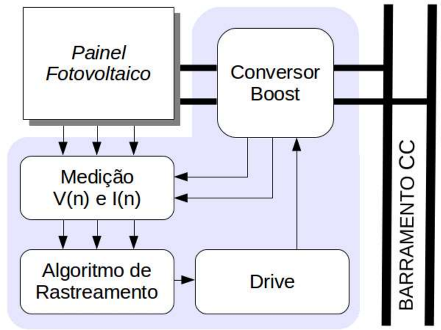

Figure 4. Block diagram of the simulated system.

The parameters of the solar panel used in the simulation, illustrated in Figure 5, were taken from the datasheet KC200GT model Kyocera Japanese manufacturer.

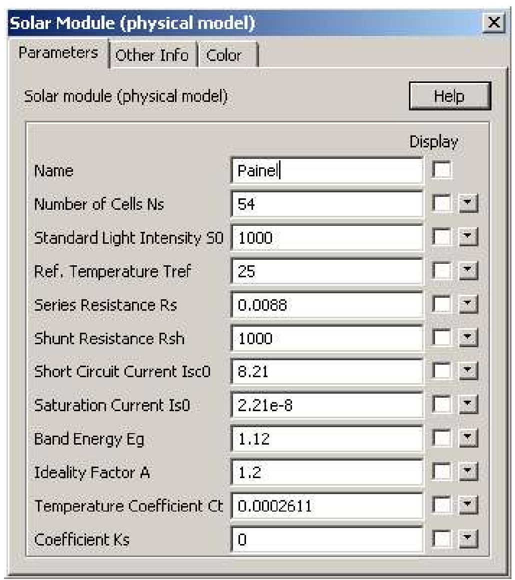

Figure 5. Features solar panel module in PSIM.

The converter components were calculated according to the equations (2), (3) and (4), using a 10 kHz switching frequency, 48 V DC bus voltage (varying between 0,5 V more or less) and the parameters of the panel chosen (Figure 5).

According RASHID (2001), the minimum capacitance (C_{min}) of the converter is calculated by equation (2) taking into account the duty cycle (D), the maximum output current (I_{0max}), the voltage of ripple (V_{rip}) and the system frequency (f).

$$C_{\min} = \frac{D \cdot V_o}{V_{rip} \cdot R \cdot f} = \frac{D \cdot I_{0\max}}{V_{rip} \cdot f} = 587.81\ \mu F \qquad (2)$$

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According to MOHAN, the current in the inductor (I_L) is calculated by (3), where the minimum inductance (L_{min}) can be found at (4).

$$I_L = \frac{V_o}{2 \cdot f \cdot L} \cdot D(1-D)^2 \tag{3}$$

$$L_{\min} = \frac{V_{0\max}}{2 \cdot f \cdot I_{L\min}} \cdot D_{\min}(1-D_{\min})^2 = 446.98\ \mu H \tag{4}$$

For the capacitance and inductance, greater values than the minimum were used, to guarantee the functioning of the converter in a continuous way for the current. Even in relation to the components used, the internal resistance was considered, and, in the bus, drops in voltage, resistance representation and parasitical inductance, aiming to approximate, a little more closely, a real experience, as shown in Figure 6.

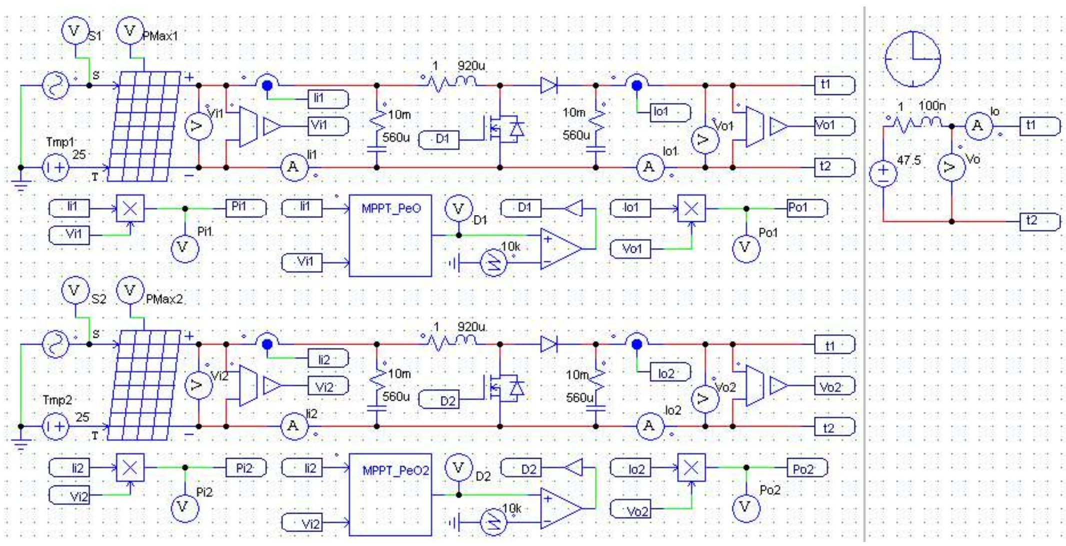

Figure 6. Complete system simulated using the PSIM software.

6. RESULTS OBTAINED

To obtain results of the comparison between the methods, the same adjustments were used in the parameters of initiating and sampling, and the values for irradiance and varying temperatures, in order to obtain different outputs from the panel. Stretches of irradiance were simulated between 100 W/m² and 1100 W/m² with a linear variation through a sinodal function and discreet variation in the form of degrees, according Figure 7 (a) and (b). The input temperature, when not fixed at 25 ºC, was varied lineally between 25 ºC and 45 ºC through a sinodal function, as illustrated in Figure 7 (c).

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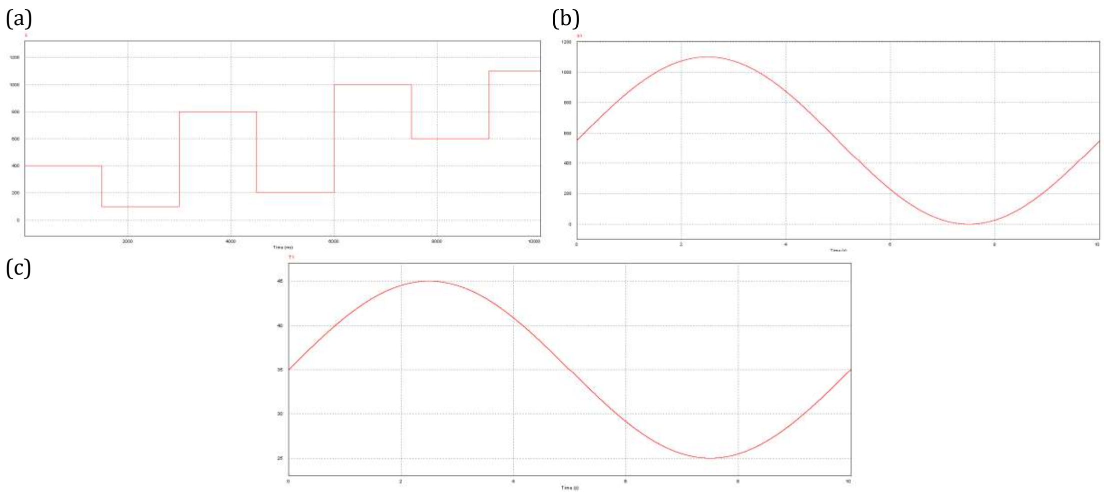

Figure 7. Signals applied to the photovoltaic panel - (a) Steps of irradiance; (B) Seno function of irradiance; and (c) Seno function of temperature.

To test the variation in irradiance in degrees switching was used in intervals of 100 W/m², 200 W/m², 400 W/m², 600 W/m², 800 W/m², 1000 W/m² and 1100 W/m² with periods of 1.5 s, as shown in Figure 7 (a) and a fixed temperature in 25 ºC. In Figure 8 graphics are shown with the maximum power provided by the panel in blue and the power obtained by the system in red, with the main graph showing the result of the method using the ΔP algorithm and the second graph using the traditional P&O algorithm.

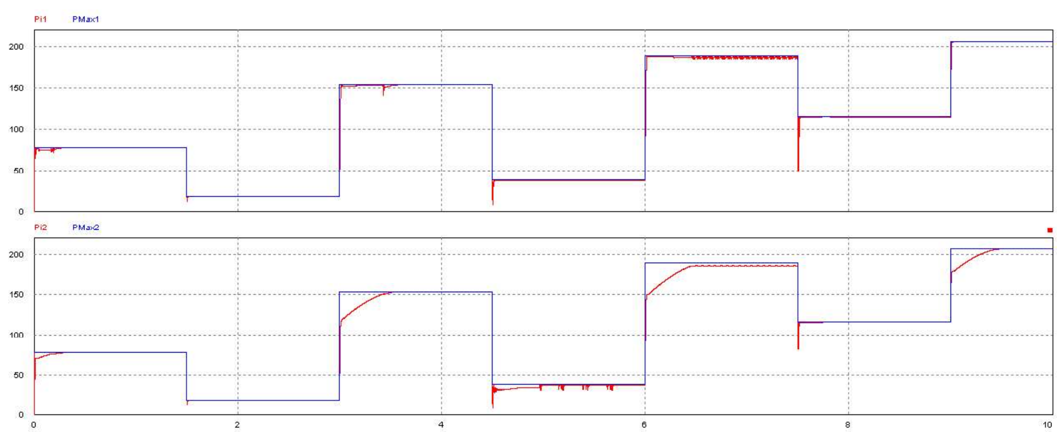

Figure 8. Graphics comparing maximum power reference values and simulated with variation in irradiance of steps obtained in PSIM software.

In Figure 9, results of the panel power are shown with the irradiance variation in a linear fashion through the sinodal function varying between 100 W/m² and 1100 W/m², as shown in Figure 7 (b), with the fixed temperature at 25 ºC, the maximum power provided by the panel in blue color and the power obtained by the system in red color, the first graph being the result of ΔP algorithm and the second with P&O algorithm.

In the third text, a linear temperature variation of the panel used a form of varying sinodal wave, varying between 25 ºC and 45 ºC, as shown in Figure 7 (c), and fixed irradiance at 800

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W/m^2. The results are shown in Figure 10 - the first graph being the result of ΔP algorithm and the second of the P&O algorithm, both with the maximum power in blue color and the power obtained in red color.

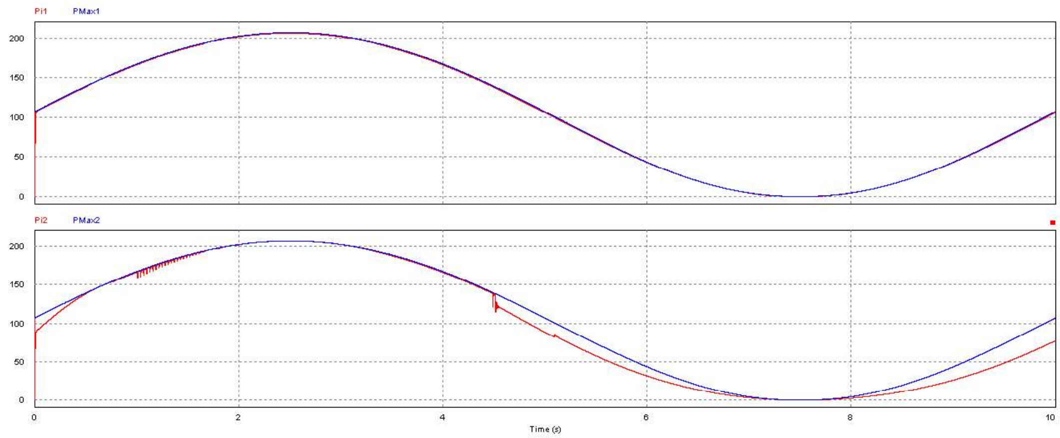

Figure 9. Graphs comparing peak values of power and reference simulated linear variation of the temperature, obtained in the PSIM software.

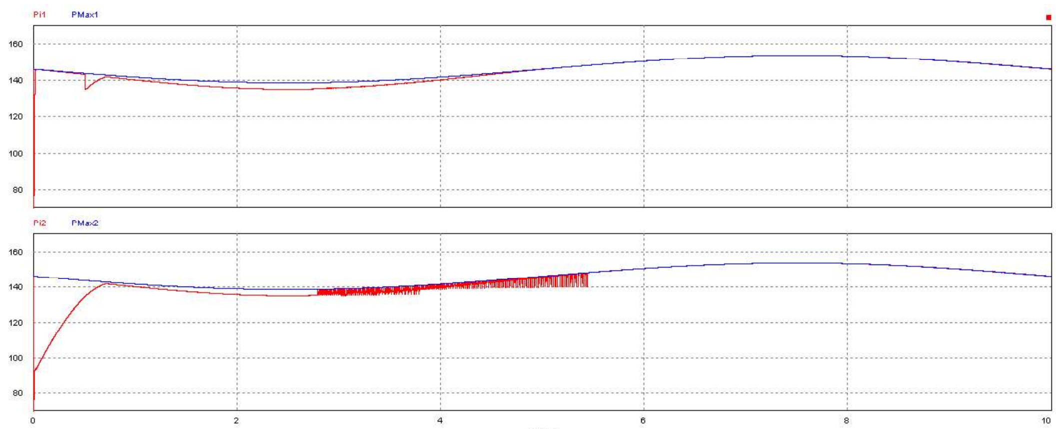

Figure 10. Graphs comparing maximum power reference values and simulated with linear variation of irradiance obtained in PSIM software.

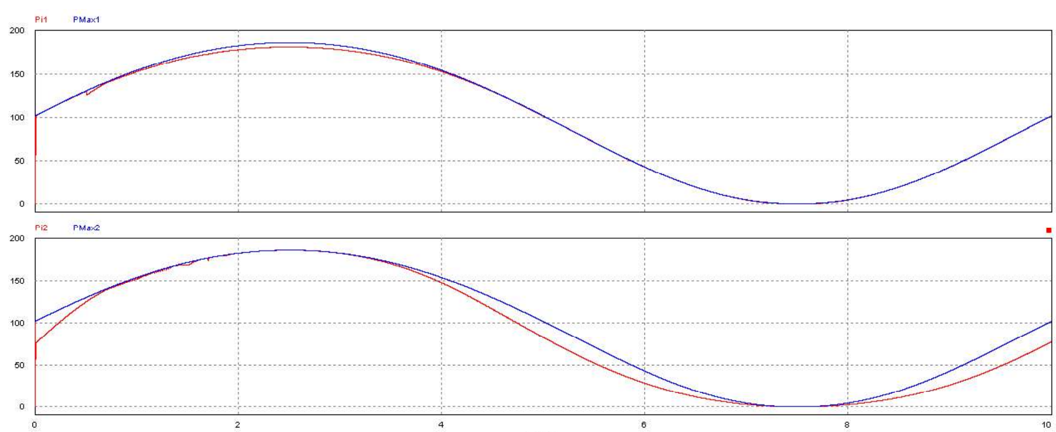

Figure 11. Graphs comparing peak values of power and reference simulated with linear variation of irradiance and temperature obtained in the PSIM software.

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For the simulation of the typical situation, with the proportional temperature and irradiance, a variation of irradiance and temperature was applied to the photovoltaic panel, as shown in Figure 7 (b) and temperature as shown in Figure 7 (c), both varying in a sinodal way and in the same phase, with the irradiance between 100 W/m^2 and 110 W/m^2 and temperature between 25 ºC and 45 ºC. The graph in Figure 11 shows the panel's output power (red) and maximum (blue), in order, for the proposed algorithm and for the traditional method. In Table 1, the summary of the results in the simulations obtained are shown.

Table 1. Summary of simulated results.

Results	**Simulation**			
	(1)	**(2)**	**(3)**	**(4)**
Maximum power panel (W)	109,88	104,92	146,27	97,17
Power extracted – ΔP algorithm (W)	106,64	97,76	143,61	88,98
Power extracted – P&O algorithm (W)	108,93	104,17	145,12	95,77
Performance - ΔP	0,99	0,99	0,99	0,99
Performance - P&O	0,97	0,93	0,98	0,92
ΔP algorithm the performance gain of the P&O (%)	2,15	6,56	1,05	7,63

7. CONCLUSIONS

Studies that aim to increase the performance of the current systems that operate with alternative energy sources are a prime necessity for the continuation of the electric energy supply in the near future – photovoltaic sources being the major prospect in growth in this area. Contributing to the popular P&O method of MPPT, the ΔP method uses the same parameters and structure, presenting advantages with relation to the first and improving tracking results. Simulations were carried out to compare methods, changing only the algorithm used, with the converter linked between a photovoltaic panel using different variations of irradiances and temperatures and an DC bus. The results obtained through graphs and summary tables show a gain in performance of the contribution proposed of more than 7.5 % in comparison with the traditional method, proving the effectiveness of the new algorithm and thereby collaborating with the national technological development of renewable energy.

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