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PHOTOVOLTAIC MPPT CONTROL USING SEPIC CONVERTER BASED ON SUPER TWISTING CONTROL

GUERBOUZ Abdesselam[1],Imad merzouk [1],Ahmed HFAIFA[1],Amine fihakhir [2]
[1] Electrical Engineering Department, Faculty of Sciences and Technology, University of Djelfa, BP 3117 Djelfa ,Algeria.
[2]Faculty of Science and Technology University of Ghardaia, BP 455 Ghardaia, 47000, Algeria
e-mail address : abdesselam.guerbouz@univ-djelfa.dz

Abstract ***For ensuring a greener and low carbon future; renewable energies sources such as solar energy stands out as a prominent solution for generating sustainable and clean electricity due to its accessibility, abundance and numerous benefits. The use of solar panel also called as photovoltaic systems has more importance in the world for their ability to convert sun irradiation into electricity while they have significant drawbacks like the nonlinearity of Pv panel. The efficiency and performance of Photovoltaic (PV) systems can be influnced by various factors, like climate fluctuations during the day. Therefore, it is so important to optimize the power capturing from PV panels. To optimize the energy created by photovoltaic modules, it is necessary to carefully select a DC-DC converter with MPPT control. This guarantees that the maximum power is extracted from the solar power plant and sent to the demand side in less time and with greater effectiveness. This paper introduces a super twisting sliding mode control technique for achieving maximum power point tracking (MPPT) in a photovoltaic (PV) system. The Single Ended Primary Inductor Converter (SEPIC) is proposed as a superior alternative to the conventional boost dc-dc converter, as it enables the extraction of the highest possible power from the photovoltaic panels array. Upon doing a thorough comparison of the suggested control with the P&O algorithm in various scenarios using the MATLAB/SIMULINK tool, it was found that the provided STC (Synchronous Tracking Control) for the SEPIC converter demonstrates greater efficiency and reduced oscillation around the Maximum Power Point (MPP).***

Keyword: super twisting, PV, SEPIC, MPPT

1. INTRODUCTION

The production of electrical energy using fossil fuels has traditionally provided adequate costs. In fact, the fossil energy production is responsible for 40% of global CO2 emissions. In this context, renewable energies like solar energy are chosen as a remedy for the decline of oil and gas and to fulfill a significant portion of the increasing energy needs at more affordable rates, while also decreasing CO2 emissions [1]. Photovoltaic electricity production has seen an increase in interest in recent years where photovoltaic panel systems ensure transforming of sun irradiation into usable electricity While the efficiency of these systems is improving, their yields still remain relatively low at around 20%. Therefore, it is crucial to maximize their power generation by minimizing lost energy.

Although there are a couple of significant shortcomings to PV panels, they are still able to generate the greatest amount of power regardless of weather condition due to their unique point of operation and non-linear output properties.
For that solar energy systems must adapt to changing climatic condition and mitigation the impact of non-linearity to ensure maximum energy production. The answer to this challenge the proper system design and sizing also maximum power point tracker are crucial to optimise energy production from pv panels.

In this respect, a huge number of MPPT control techniques are already developed in recent years [2] , additionally for MPPT, the power electronics especially DC-DC converters are employed to maximize the performance of the PV panel [3].
In recent papers, many methods for different DC-DC converters type have been developed. The famous methods are P&O and IC [4]. Trough the P&O the voltage is lowered and raised with a precized step size to attain the maximum power point. The negative of this technique is huge fluctuations around the MPP. The IC and the P&O has the same principe, it determines the MPP point by observing the pitch of a PV power curve, it is reached at the point where the slope becomes zero. [5]

MPPT methods can be devided as current loop controller [6] or a voltage loop controller [7] ; we can also find that many different methods for MPPT in the literature are developed among the artificial intelligence like ANFIS-based MPPT [8], PS0[9] , fuzzy logic controller (FLC)[10] , neural networks (NN)[11] and genetic algorithm[12] ; To address the issue of oscillations around the MPP, one possible solution is to employ a nonlinear control technique, including sliding-mode control[13] and backstepping [14]. These control algorithms'use results were improving the efficiency of MPP tracking. They have been extensively studied and implemented in scientific literature.

The non-linear sliding mode control (SMC) is a known technique wich has significant advantages in its robustness against model uncertainties or several classes of perturbations;
But its significant drawbacks is chattering phenomena; one of the best solution reduce SMC drawback is the use of novel super twisting control; wich is a control method that has There

multiple benefits in terms of monitoring accuracy and the ability to handle disruptions and resilience, including[23]:

- Robustness: STC is renowned for its ability to withstand fluctuations, uncertainties, and nonlinearities in the model. Because of its ability to efficiently manage both external disturbances and parameter fluctuations, it is well suited for situations where exact modeling is challenging or impracticable.
- Chattering reduction: Chattering, or high-frequency oscillations surrounding the sliding surface, is one of the primary problems with classic sliding mode control. Chattering might lead to unfavorable control behaviors. However, STC addresses this issue.
- High tracking accuracy: The required trajectories may be precisely tracked by STC. It can track with great precision even when there are uncertainties and disturbances.

The paper's aim is to supply a SEPIC converter MPPT control in order to boost its robustness and efficiency, the MPPT based on super twisting control (STC). The effectiveness of the recommended method has been evaluated under three scenario. An evaluation has been conducted to compare the outcomes obtained from the STC method with those obtained from the P&O. This research is divided as stated below: The system being examined is explained in part 2, while the results of the simulation and disscussed are presented in part 3. part 4 analyzes the conclusions.

2. THE SUGGESTED STC MPPT

Figure 1 illustrate the whole regulated system for the SEPIC, which is based on STC Control. The proposed STC and utilize PV voltage and current as inputs to regulate the MPPT.

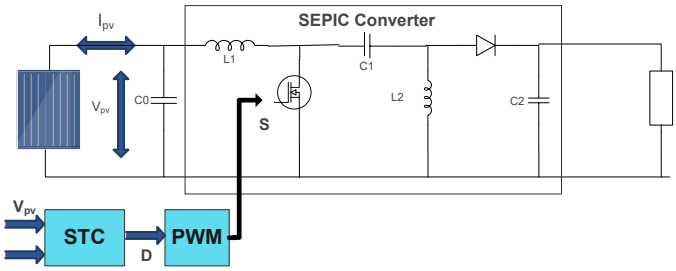

Figure.1. The proposed system

a) Proposed STC control for SEPIC

Sliding mode control, known from widely as the nonlinear control is a standard control method. It consists of two parts: find the sliding surface and establishes the control loop which will control all part of system's behaviour to reach and remain inside the designated surface. [16]

From the curve of pv power we obtain the desired MPP as follows:

$$\frac{dp_{pv}}{dv_{pv}} = \frac{dv_{pv}I_{pv}}{dv_{pv}} = I_{pv} + v_{pv}\frac{dI_{pv}}{dv_{pv}} = 0 \qquad (1)$$

Consequently, we can determine the sliding surface to get the maximum power point as follows:

$$\psi_{pv} = I_{pv} + v_{pv}\frac{dI_{pv}}{dv_{pv}} = 0 \qquad (2)$$

If $\psi_{pv} < 0$, then (dPpv/dVpv) is less then 0 , The operating point is positioned to the left of the MPP.

In case of $\psi_{pv} > 0$, so (dPpv/dVpv) is greater then 0, The operating point is positioned to the right of MPP.

The equation for the super twisting control to track the maximum power point (MPP) is as described below [17]:

$$\mathbf{D} = -K_1\sqrt{|\psi_{pv}|} * sign(\psi_{pv}) - \int K_2 sign(\psi_{pv}) \qquad (3)$$

Where K_1; K_2 : positive constants selected by the designer.

b) P&O

A popular technique in MPPT for maximizing power production in solar systems. Using this mechanism, the controller measures power and modifies the voltage from the array slightly. If the power grows, the changes are made again until the power stops increasing. This technique, which is sometimes referred to as a "hill climbing method," uses the power-voltage curve's rise and fall to determine the MPP. Figure. 2 displayed the P&O diagram.

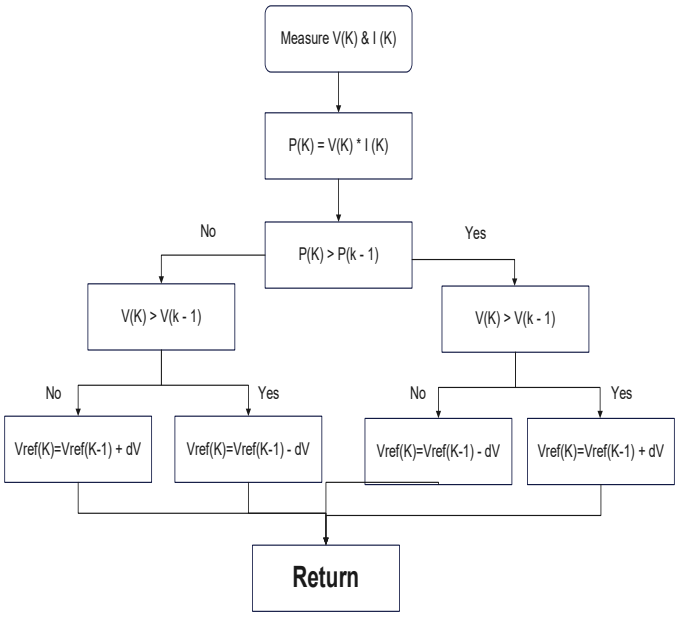

Figure.2. P&O flowchart

c) Sepic converter

Diverse dc-dc converter topologies exist, each with distinct limitations and design characteristics.[18], for example, boost converter, buck converter [19], cuk converter [21], and zeta converter [20]. SEPIC behaves as the known buck–boost dc-dc converter that can either decrease or increase voltage, depending on the duty cycle value.

The SEPIC converter was created by Slobodan Cük in the late 1970s. The structure of the SEPIC is derived from the capacitive chopper known as Cük through the rearrangement of the diode and the output inductor. It shares similarities with the Cük, but it functions as a non-voltage inverter. This electrical power converter topology enables the regulation of the output voltage and provides galvanic insulation between the input and output. This configuration is frequently employed in scenarios where the input voltage exhibits substantial variations, such as battery-powered devices or renewable energy sources.

The sepic converter offers the benefit of a continuous output current, enabling parallel connection of converter outputs or conversion to a voltage source with minimal capacitance. [22] We use sepic converter to optimize pv panel in the mpp tracking, the sepic converter circuit is shown in figure. 3 as below

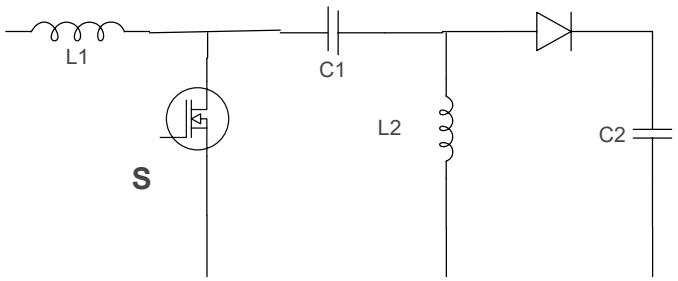

Figure.2. SEPIC CONVERTER.

operation of sepic is done in two parts according to the conduction state of the switch S.

- from 0 to ST :

where S considered as duty cycle and T is the period time ; During the conductive phase, the element K is in the ON state, allowing current to pass through. The voltage at the ends of the inductor L1 is equal to the input voltage. The capacitor C1 is linked in parallel with the inductor L2, and the terminal voltage of L2 is equivalent to the negative of the input voltage, which is also equal as the voltage across the capacitor. The diode is in reverse polarization, therefore it is blocked and does not allow current to flow. The C2 capacitor supplies the current for the charge, which is then stored in L1 by the input and in L2 by C1.

- from ST to T :

When the K switch is turned on, the D diode begins to operate. During the recovery phase, the switch S is in an inactive state (OFF), causing the current in L1 to flow via C1 and diode D, and then into capacitor C2. This process charges capacitor C1, preparing it for the following cycle. Furthermore, the electric current present in L2 flows through C2, causing the charge in C2 to move and prepare it for the subsequent cycle (Figure 4).

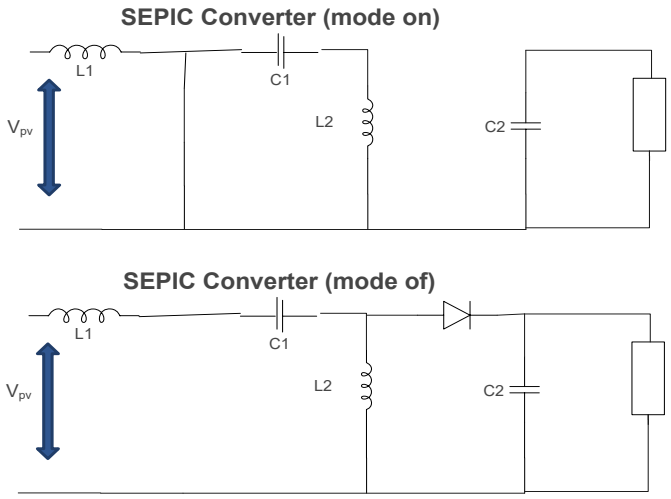

Figure.4. SEPIC converter operation.

3. RESULT AND SIMULATION

The proposed method is simulated in MATLAB Simulink, the stc's behaviour is tested and compared with the P&O. The simulink model covers the suggested system, a sepic converter, The suggested system is an MPPT (Maximum Power Point Tracking) and PV (Photovoltaic) system developed by STC. The PV panel consists of a single 200W PV module. The table below presents the features of the PV module. The sepic elements values for the simulation were chosen as follows: The numerical values of the components are as follows: Cin = 10 mF, L1 = 298 µH, L2 = 298 µH, C1 = 106.2 µF, C2 = 47 µF, and Rload = 16 ω. The specific features of the PV panel are presented in 5 shows.

TABLE I. PV MODULE PARAMETER

PV PARAMETER	VALUE
P_{MPP}	200 WATT
V_{MPP}	26.31 V
I_{MPP}	7.61 A

Voc	32.9
Isc	8.21 A

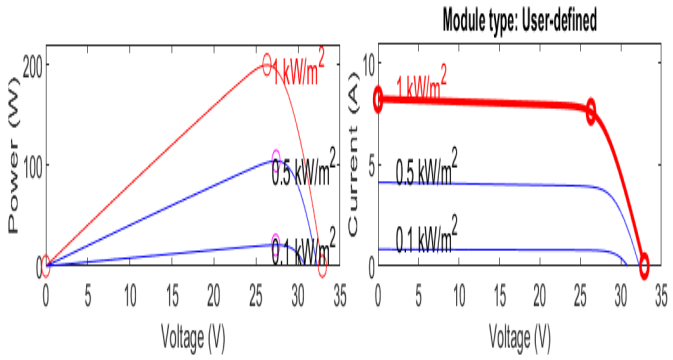

Figure.5. PV MODULE CHARACTERISTICS

a) Test 1: Fixed temperature and the irradiation

In this scenario, the temperature and irradiation levels are kept constant at 25°C and 1000W/m2, respectively. The outputs of the PV system including power, voltage and current are displayed in the following Figures : Figure 5, Figure 6, and Figure 7, respectively.

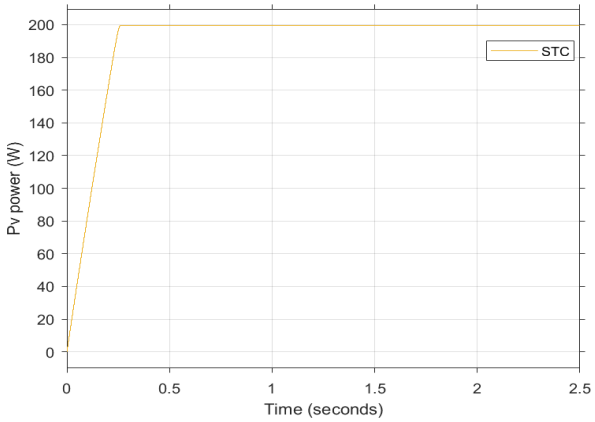

Figure.6. PV power of proposed STC

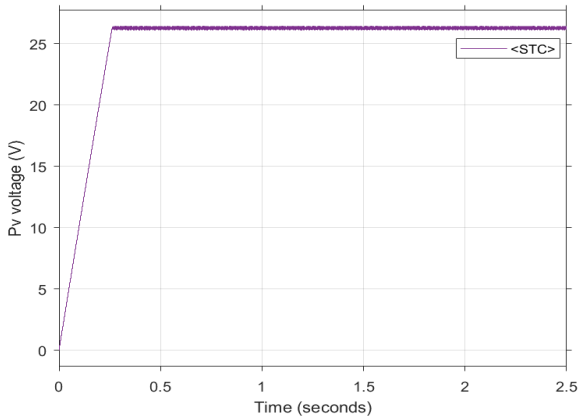

Figure.7. PV voltage of proposed STC

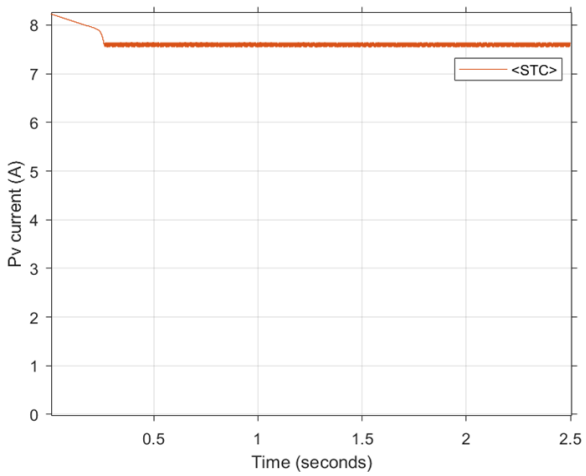

Figure.8. PV current of proposed STC.

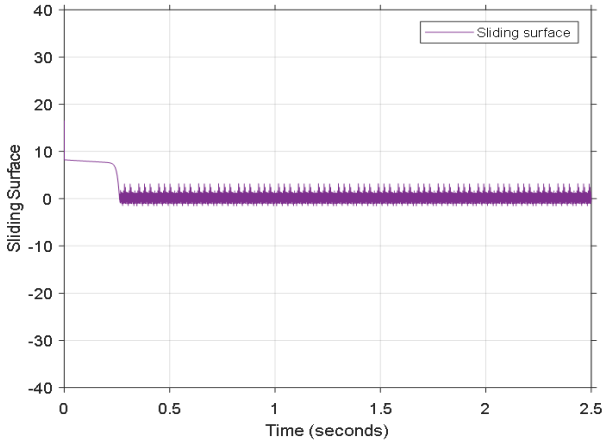

Figure.9. The selcted sliding surface.

The simulation results in figure. 6, 7, and 8 indicate a very good response and perform tracking when using STC. The MPP is reached in 0.198 seconds. Moreover, the oscillations are so unobvious in the steady case.

Figure 9 shows the sliding surface, it can be seen that is around the desired trajectory, and attaint the equation (1) by conclusion tracking the mpp.

b) Test 2: Variation of irradiation

To test robustness of the STC MPPT, We manipulate the irradiance, while keeping the temperature as shown in figure 10 constant at 25 °C.

The figures of power, current and voltage of the studied mppt algorithms (P&O, STC) at different irradiance cases are clarified in Figures 11, 12, and 13. It can be noticed that the P&O algorithm has a huge variation around the maximum power and bad control

performance and, with large power fluctuations under irradiation change. The proposed STC MPPT demonstrates excellent efficiency in achieving maximum power, regardless of variations in irradiation levels.

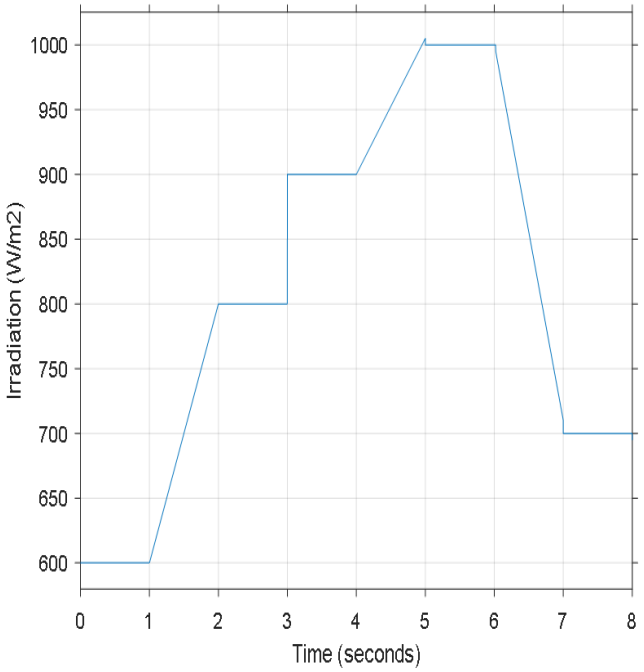

Figure.10. The different irradiation levels changes

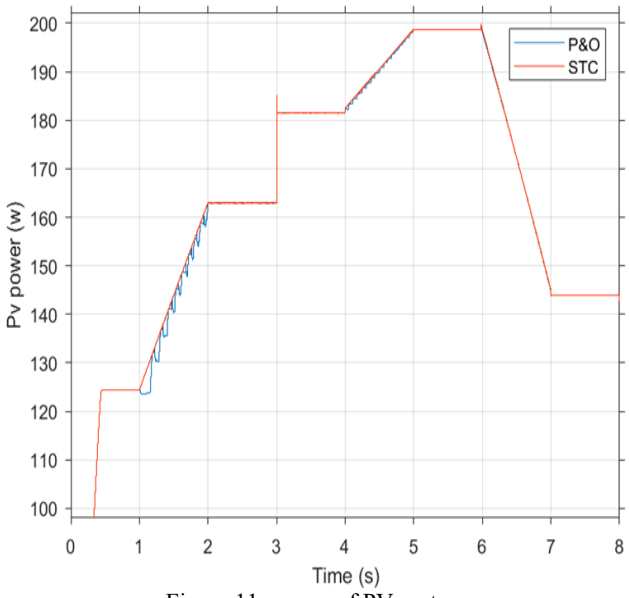

Figure.11. power of PV system

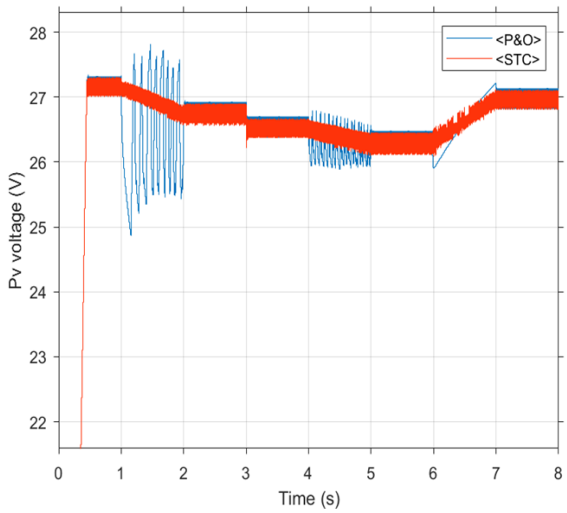

Figure.12. Voltage of PV system

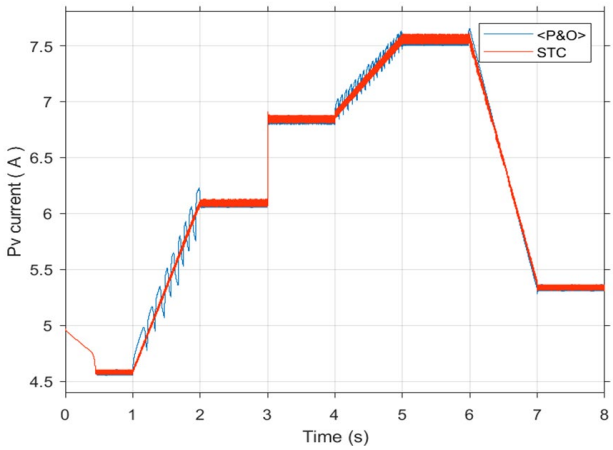

Figure.13. Current of pv system

c) Test 3: Variable Temperature and Irradiance

To evaluate the robustness and resilence of the proposed STC, variable temperature and irradiance are applied at the same instants as showin in Figure 14.

The simulation results at varied irradiance and temperature conditions are presented in Figure. 15, 16, and 17. As can be noticed, the proposed STC maintain the same performance under varying temperature and illumination conditions and show powerful robustmess under any climate change; on the contrast of the traditional P&O algorithm has a huge perturbation and significant instability and bad control performance with significant power fluctuations under climate change.

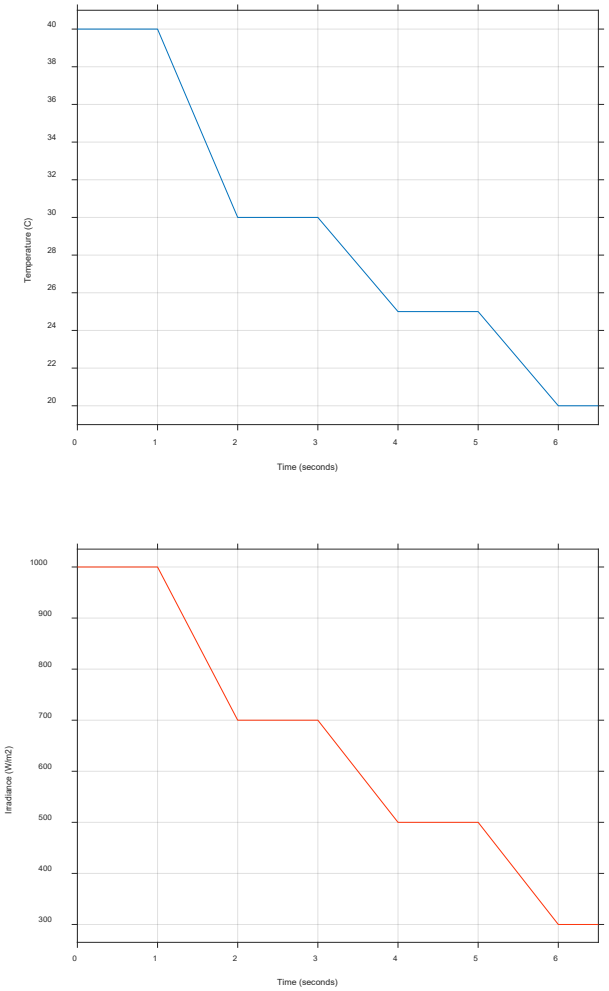

Figure .14. Variable irradiance and temperature

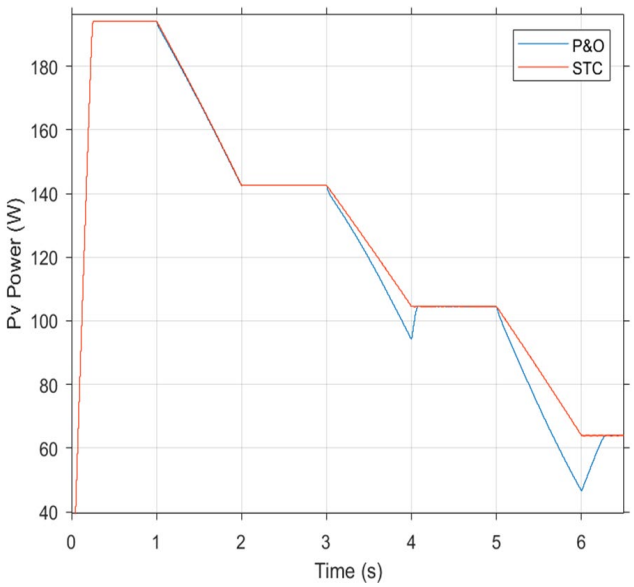

Figure.15. Output power of PV system

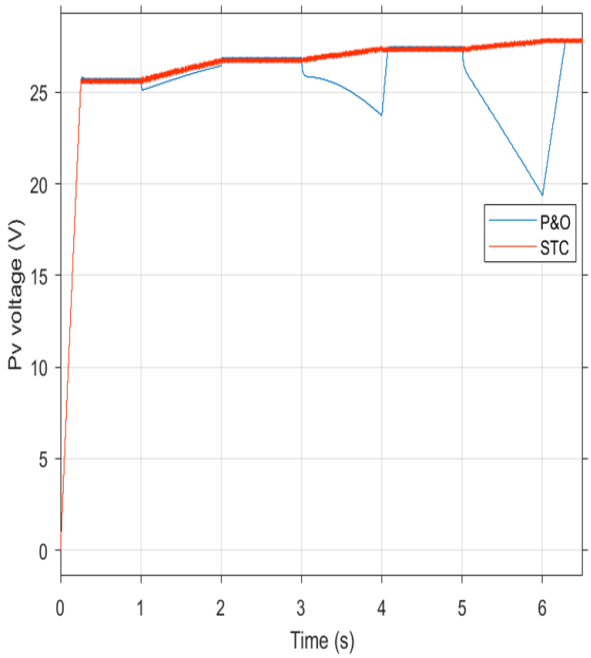

Figure.16. Output Voltage of PV system

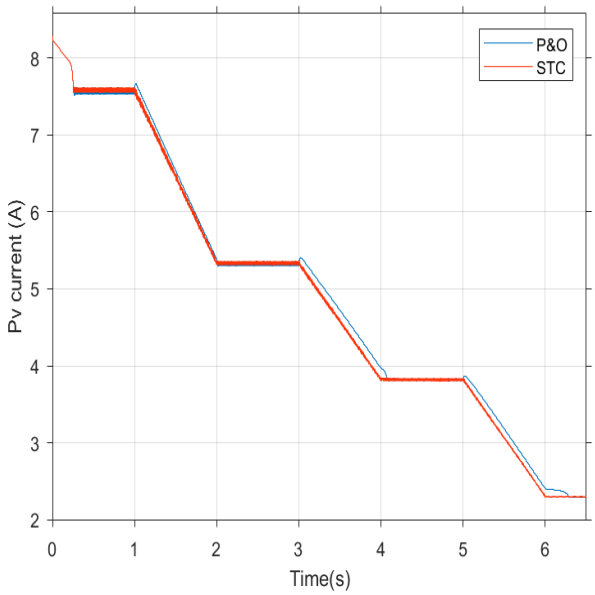

Figure.17. Output Current

To summurize, the previous MPPT algorithms effectiveness was evaluated in each of the previous scenarios' dynamic environmental settings. Their findings support the STC algorithm's exceptional performance, which is characterized by a quick reaction time, small power fluctuations, and strong resilience.

Table II conclude the obtained comparaison between the tested MPPT methods.

TABLE II. MPPT's Comparison

Aspect	P&O	STC
Precision in tracking	Bad	good
efficiency of Power	Not good	excellent
Tracking speed time	lent	acceptable
Steady state fluctuation	Huge	Very small

4. CONCLUSIONS

This article suggest the use of a super twisted controller for MPPT in conjunction with a SEPIC converter. The efficiency of the suggested MPPT was compared with the P&O method. The prior simulation results indicate that the provided STC offers greater flexibility. They offer improved effectiveness for optimal point tracking, resulting in reduced oscillation power and rapid convergence speed, while also delivering heightened precision in reaction to environmental changes.

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