Journal of Renewable Energies

Revue des Energies Renouvelables

journal home page : https://revue.cder.dz/index.php/rer

A new adaptive MPPT design for photovoltaic system under real outdoor conditions

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Abstract

Renewable energy, especially solar photovoltaic (PV) panels, have been widely integrated into energy systems, indeed, this technology is eco-friendly and available almost everywhere. However, these systems exhibit some challenges in regards their performance. They must always track the maximum power point (MPP) to provide the highest power. This work investigates a novel maximum power point tracking (MPPT) procedure. In the suggested tracking system, a novel controller is applied to establish different operating regions. In both regions, the step is changed depending on the closeness to the MPP. Due to this technique, some disadvantages of the incremental conductance (IncCond) approach are avoided. The proposed method offers reliable and stable behaviour under rapidly changing atmospheric conditions. Moreover, it is easy as it does not need additional sensors. The theoretical assessment discussed in this investigation is validated by simulations via MATLAB/Simulink and experimental outdoor tests. A comparison with conventional MPPT approach is provided to emphasize the performance of the developed MPPT technique.

Keywords: IncCond, MPPT, SEPIC Converter.

1. Introduction

In the last few years, PV technology has achieved remarkable improvement as an alternative to overcome energy challenges, especially in Sahara environments, due to increasing environmental concerns and decreasing prices of PV-panels [1]. Cost-efficiency and performance are the fundamental requirements, as a PV installation should be implemented with good yield at minimal cost. In addition, PV-array have nonlinear output curves, and the major parameters that influence the PV panel are irradiance and the impedance of the load [2]. Due to the nonlinear characteristics of PV-array, MPPT tracking is mandatory to achieve the maximum performance.

Numerous investigators have focused on MPPT approaches for PV-panel such as IncCond. Generally, the major disadvantage of traditional MPPT approaches is the choice of the step-size, which is a compromise between the fluctuation and the tracking velocity [3].

To overcome these limitations, this study suggests a novel self-scaling IncCond MPPT technique. The proposed strategy generates two different operating zones depending on the proximity of the desired MPP, where the step-size varies between two different values. The proposed strategy is unlike other techniques because does not need scaling factors. A comparative experimental study of the traditional and suggested MPPT technique is discussed in this paper. The efficiency of the suggested approach in terms of stability and tracking velocity is verified with experimental and simulations results.

2. PV system modelling

The PV-system is composed of many different parts, such as PV-modules, DC-DC converter, MPPT controller, and load. The whole PV-system is shown in (Fig. 1).

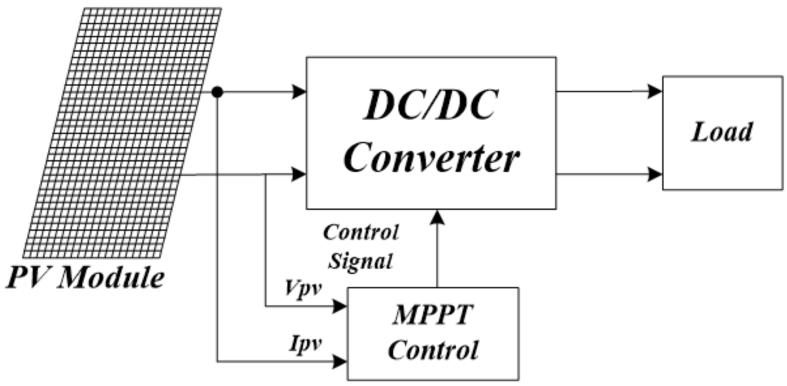


Fig 1. The whole PV-system

2.1 PV solar modelling

The essential parts of a PV installation as presented in (Fig. 2) are the PV solar cells. These later are collected in parallel and in series to form panels. Various panels are grouped depending on the required output power. The PV characteristic is depending on the irradiance and the temperature, as expressed in equation (1) [4].

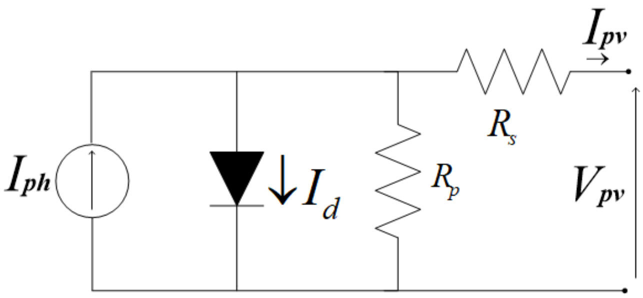


Fig 2. PV cell equivalent circuit

2.2 DC-DC converter

Choppers are generally needed to control the voltage level for the desired application. DC-DC converters are the major commonly employed in the PV installation. In this situation, the SEPIC converter (Fig. 3) is applied due to its good MPPT effectiveness. It is able to effectively control the voltage of the PV-array at various solar irradiation levels [5].

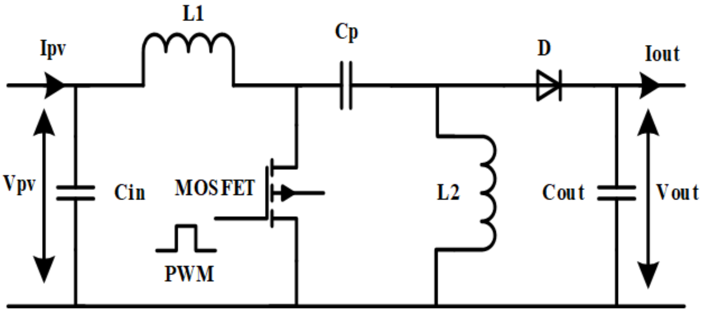


Fig 3. SEPIC Converter

3. MPPT approach description

MPPT is applied to harvest the optimal energy generated by the PV-array and forward it to the consumer [6]. This process is assumed to be the efficient way to enhance the performance of the PV-system. In this work, a modified IncCond algorithm is suggested, carried out, evaluated and compared to this traditional method under various irradiance.

3.1 Traditional incremental conductance algorithm

The IncCond technique is employed largely in the real world due to its simplicity of application. The IncCond method has certain limitations in tuning the steps. Its performance can be unstable when irradiance change abruptly. The flowchart of the standard IncCond method is shown in (Fig. 4).

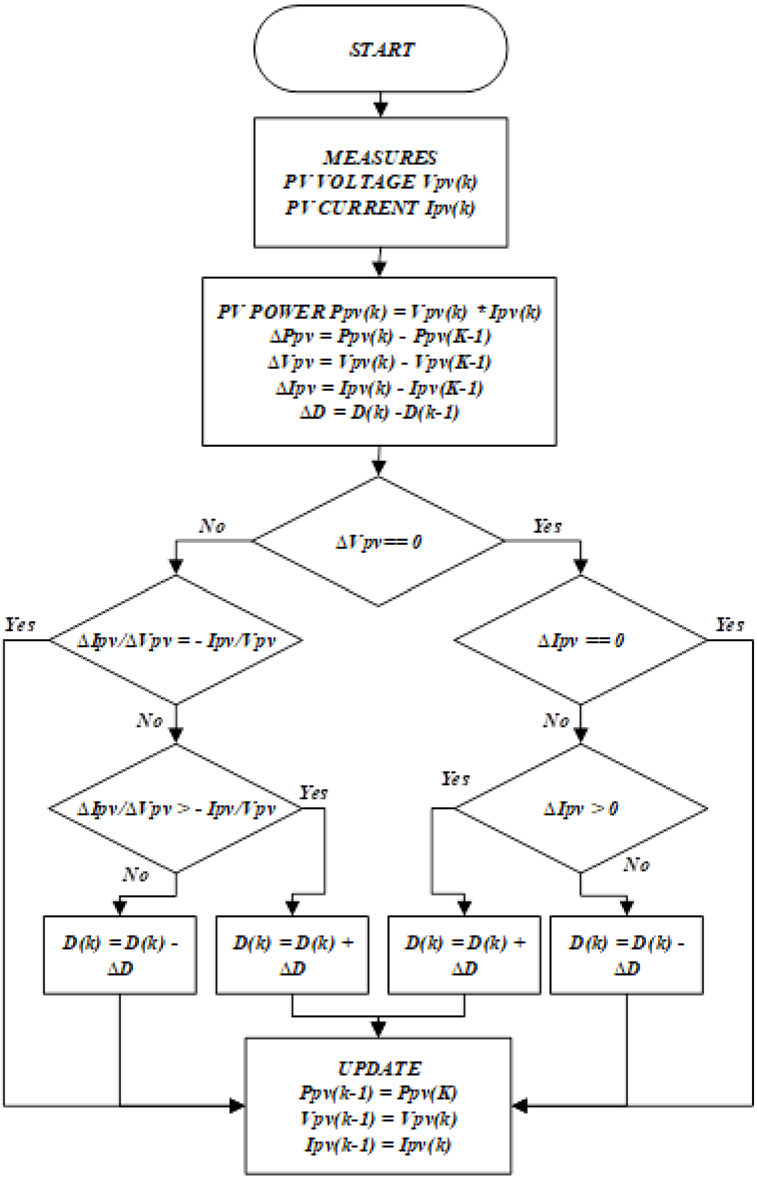


Fig 4. Flowchart of the standard IncCond method

3.2 Enhanced MPPT approach

The standard IncCond process varies according to the step; hence, when not properly adapted, it cannot effectively follow the optimal energy and results in power losses [7][8]. A big step-size leads to a fast convergence and a significant power loss. A short step-size can achieve the MPP but cannot track the fast-changing radiation. To enhance the IncCond procedure, the suggested method is enhanced the tracking precision by eliminating the fluctuations and ensure direction of tracking. The flowchart of the suggested IncCond procedure is shown in (Fig. 6). Equation (2) is set up to generate two zones of operation (Fig. 5), with Z being a very small value. Working zones, A and B have a big step (BS) and a short step (SS) respectively.

$$\left|\frac{\Delta P_{pv}}{\Delta V_{pv}}\right| \leq Z \tag{2}$$

The algorithm defines the step as BS. If equation 3 is verified and the algorithm still searches the MPP with the steps specified depending on the fields determined by (2). as (3) rarely reaches zero, a little margin of tolerance is needed: e=0.04.

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} + \frac{I_{pv}}{V_{pv}} < e = 0.04 \tag{3}$$

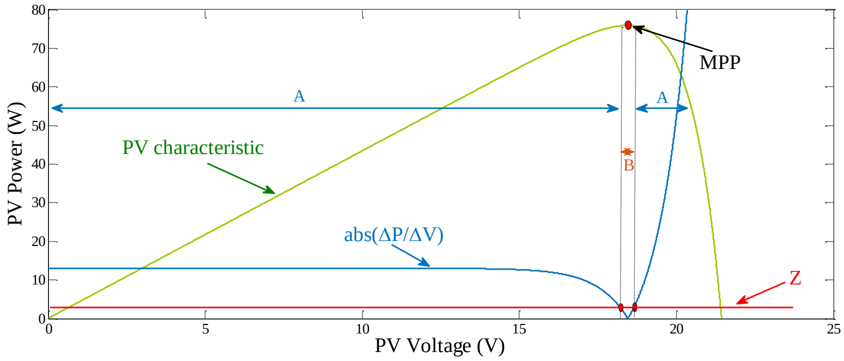


Fig 5. The operating zones

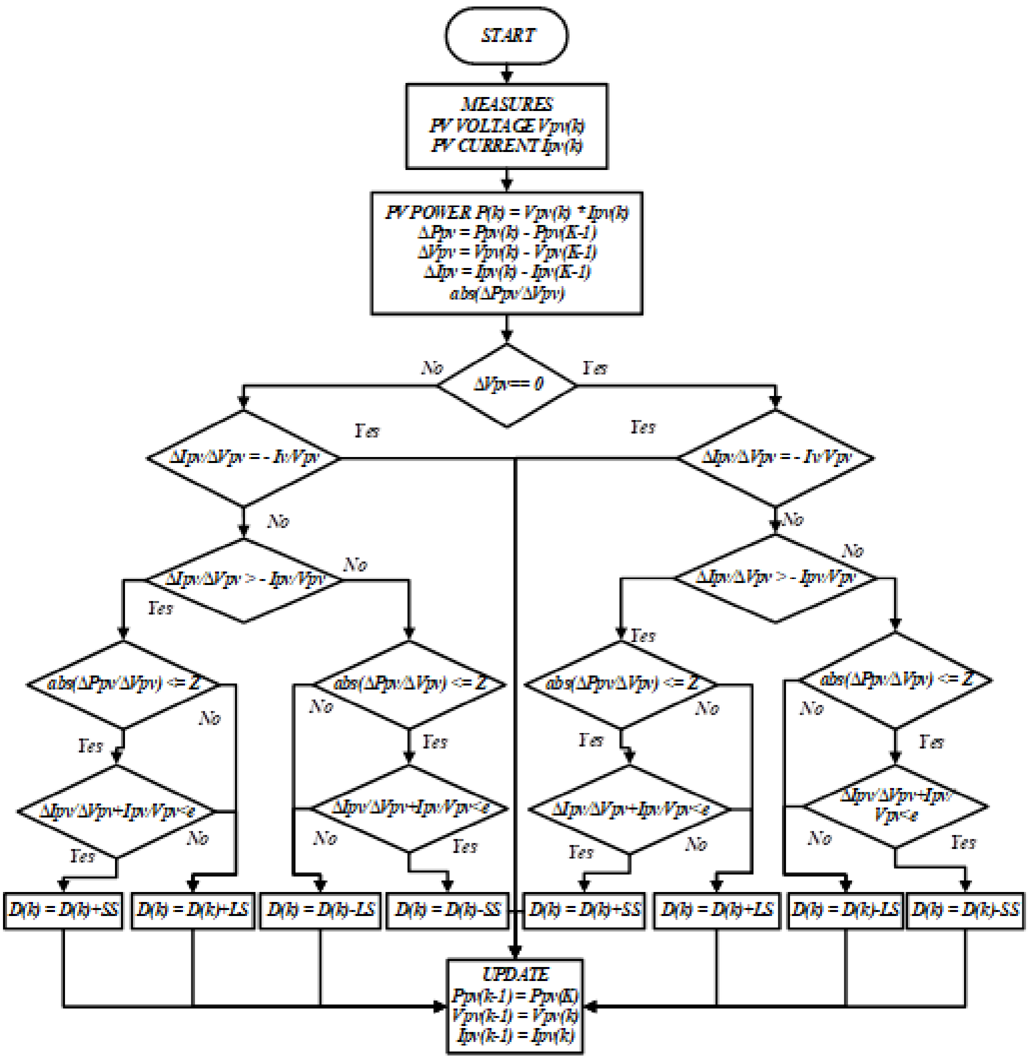


Fig 6. Flowchart of the modified algorithm

4. Simulation test

The entire offered system was tested through the use of MATLAB/Simulink. The global MPPT-system is shown in (Fig. 7).

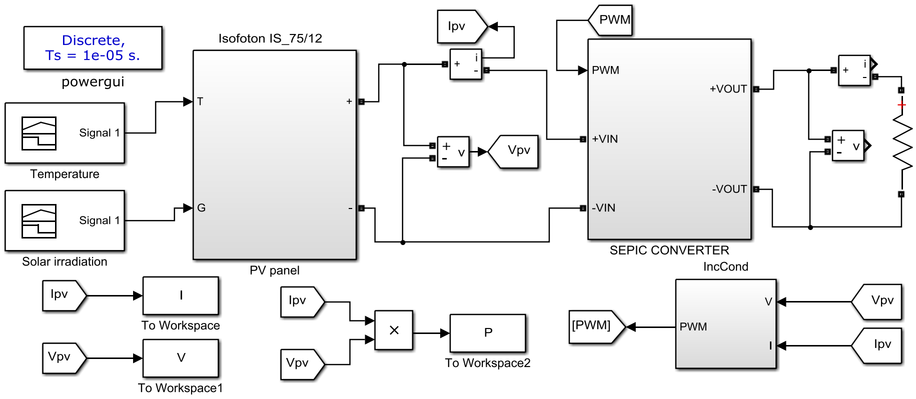


Fig 7. The entire PV-system

The simulation presented below was performed for a clouded-day. The irradiance of the selected day is presented in (Fig. 8).

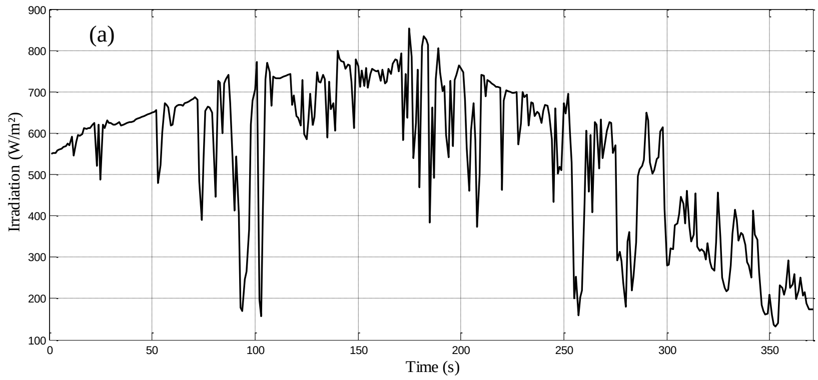
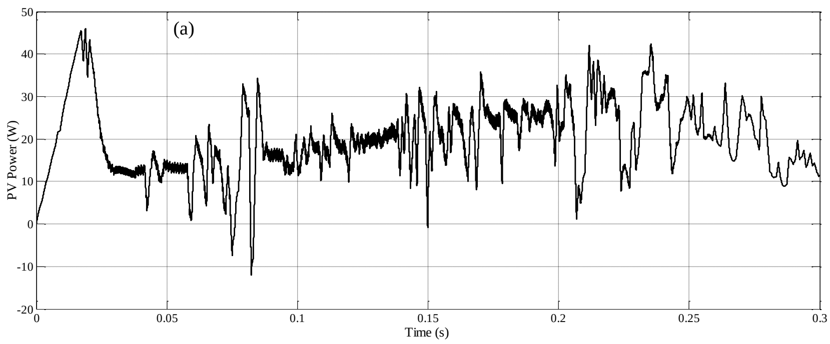


Fig 8. Real data of solar irradiance



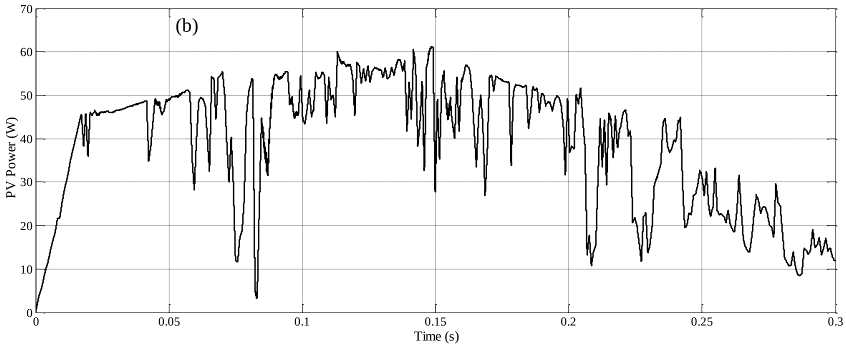


Fig 9. PV output power waves for: a) the standard IncCond method. b) the suggested IncCond technique

To observe the behavior of the suggested approach, both MPPT techniques are evaluated for Sudden irradiance variation (cloudy-day). (Fig. 9) shows that the conventional IncCond approach cannot follow the MPP properly under rapid solar irradiation change, while a successful tracking of the PPM by the offered method is noticed.

5. Experimental test

The whole experimental PV-system was realized to verify the effectiveness of the offered technique in the Saharan Adrar, Algeria is illustrated in (Fig. 10).

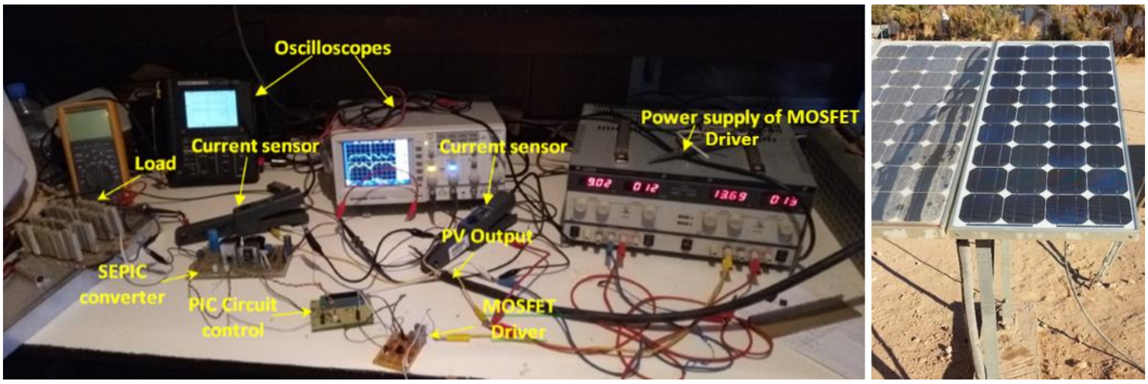


Fig 10. The whole PV-system under test.

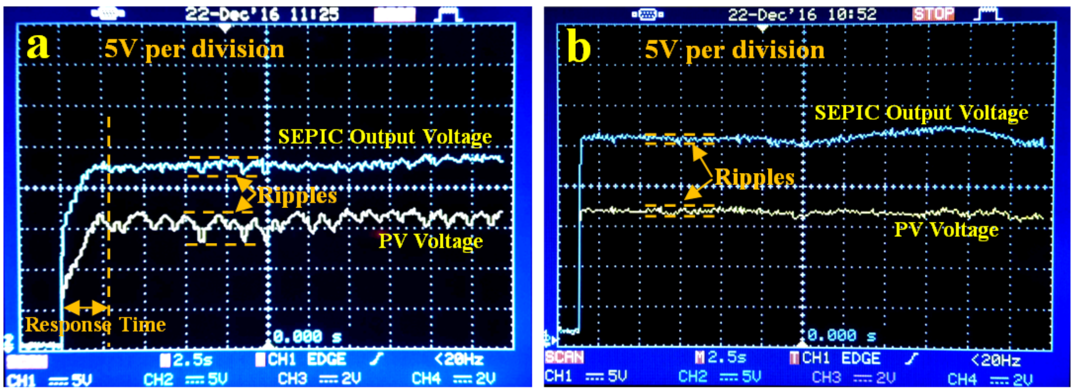


Fig 11. PV voltage and SEPIC output voltage

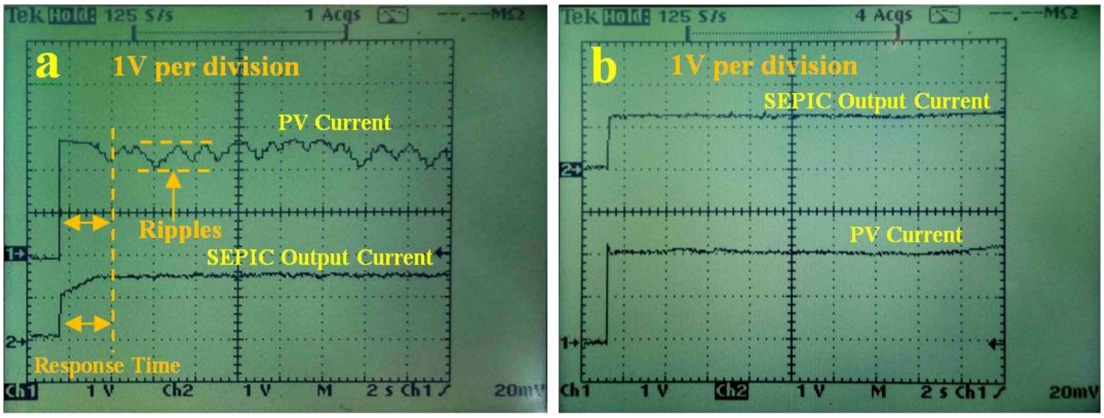


Fig 12. PV current and SEPIC output current

In (Fig. 11) the classical MPPT method causes large oscillations in the due to the size of the perturbation. In (Fig. 12) the proposed MPPT technique is able to achieve MPP with very low fluctuation and has a good response time.

6. Conclusion

In this work, a modified IncCond procedure was performed to overcome various limitations of the standard method. The achieved results prove the efficiency of the offered MPPT strategy and prove that with different types of irradiations, the PV-system performs efficiently under varying irradiance. The proposed procedure offers excellent efficiency in real data of solar irradiance in the Saharan Adrar, Algeria. The PPM is rapidly reached and the fluctuation is significantly decreased.

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