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Optimizing solar efficiency: MPPT control using PSO metaheuristics under partial shading constraint

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INTRODUCTION & AIM

Under conditions of non-uniform solar irradiance, multiple maximum power points can occur, but only one represents the overall maximum power, creating an optimization challenge. This thesis introduces an algorithm for tracking the maximum power point of a photovoltaic array in partial shade conditions (PSC) using particle swarm optimization. Simulation results demonstrate that this MPPT technique successfully identifies the overall maximum power point, avoiding stagnation at the first local peak—something traditional MPPT methods like Perturb and Observe (P&O) or Increment- decrement (IC) cannot accomplish.

METHOD

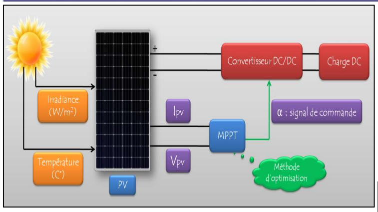

Figure 1. General architecture of MPPT

This technique - called MPPT - is used to always keep the panel operating at its maximum power point, for any temperature and irradiance applied to the PV module (Figure1).

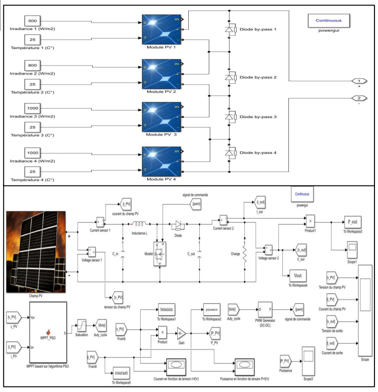

Figure 2. System's simulation

Figure 2 shows the overall simulation of the system and the mounting of the panels under different irradiances to implement partial shading conditions.

The PSO block contains the algorithm used to find the optimal voltage that corresponds to the maximum power and this at each instant, that is to say during the variation of the temperature and the irradiance and figure 3 explains the operation of the proposed optimization algorithm.

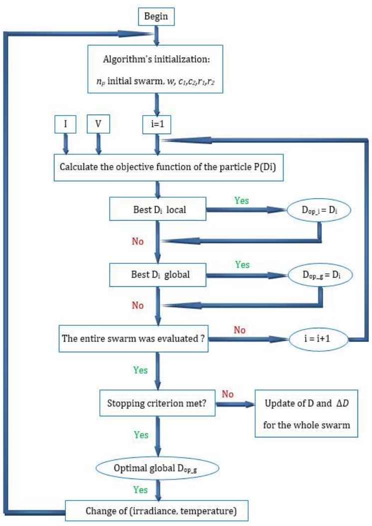

Figure 3. MPPT based on PSO

To track the maximum power point, the current and voltage provided by the PV field are captured and sent to a controller programmed based on the PSO algorithm, the latter calculates the maximum power (as explained in the previous part) produced for each i_PV and v_PV received, it then concludes the duty_cycle (between 0 and 1) which will be converted to the form of an analog signal (PWM) directly attacks the trigger of the "mosfet" to control the DC / DC converter, and this to keep the operation at a voltage called V_optimal which is corresponding to the maximum power.

In this work we applied the PSC conditions to see the results when the modules of the PV field are not exposed to the same lighting conditions (Figure 2).

RESULTS & DISCUSSION

In the P=f(V) characteristic, we notice the appearance of several maximum power points (three points in this case), one presents the desired point and targeted by the MPPT technique that we are going to apply, it is the global maximum power point and the other two are the local maximum power points that only present a power peak. This result is interpreted by the difference in the illumination between the modules of the PV field (PSC conditions) whose P=f(V) characteristic is plotted as well as the bypass diodes installed to solve the hot spot problem and ensure the safety of the PV field.

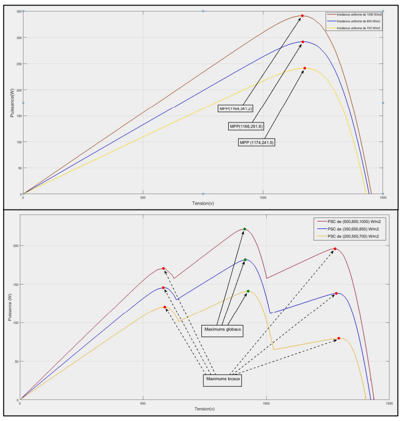

Figure 4. P=f(V) with and without PSC

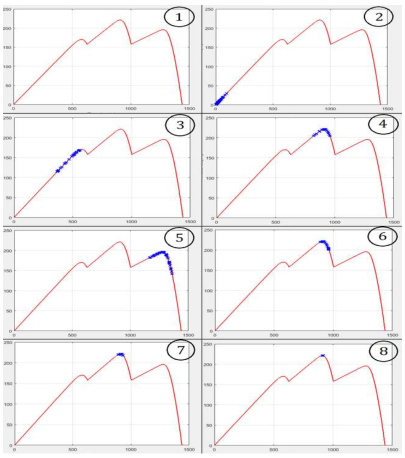

Figure 5. P=f(V), Tracking of MPP using PSO

The last two steps show the accuracy of the technique when applying the duty cycle Dopt_g, to keep the operation of the photovoltaic system at the so-called V_optimal voltage corresponding to the global maximum power point shown in the step 8. The best advantage that we must therefore point out from these results is that the applied method can reach the global maximum power point, unlike classic methods such as Perturb & Observe (P&O) and Increment Decrement (IC) which stagnate at the first peak found even if it is a peak representing a local power point.

CONCLUSION

The importance of this work is underscored by the advantages of solar photovoltaic energy, which addresses many issues associated with electricity generation from fossil fuels, such as pollution and technological complexity. Additionally, solar energy presents fewer drawbacks compared to other renewables like wind energy. However, a significant challenge is the intermittency of solar energy, which causes uneven lighting conditions; modules within the same photovoltaic field do not always receive the same irradiance, leading to hot spots in partially shaded modules. The research yielded several conclusions: (1) the power output of a photovoltaic module is affected by both its internal construction and external factors, especially irradiance, with higher irradiance resulting in increased power; (2) it is crucial to install bypass diodes in parallel with each module to ensure safety under partial shading conditions; (3) partial shading and the use of bypass diodes lead to multiple local maximum power points as well as a global maximum; and (4) the PSO-based MPPT technique effectively maintains operation at the global maximum power point, demonstrating the robustness and accuracy of this heuristic algorithm.

FUTURE WORK / REFERENCES

Ghiloubi, Imam Barket. (2020). Maximum Power Point Tracking MPPT of a photovoltaic system under Partial Shading Conditions PSC based on PSO algorithm (Master's Thesis).