

Global Maximum Power Point Tracking of Photovoltaic Systems under Partial Shading Using Crow Search Algorithm

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INTRODUCTION & AIM

Photovoltaic (PV) systems are increasingly integrated into modern energy infrastructures as a clean and sustainable power source. However, under partial shading conditions (PSC), the power–voltage (P–V) characteristic of a PV array exhibits multiple local maxima, which makes the tracking of the global maximum power point (GMPP) a challenging task. Conventional MPPT techniques, such as Perturb and Observe and incremental conductance methods, often fail in these situations because they converge to a local maximum instead of the global one. The aim of this work is to propose and apply a metaheuristic optimization approach based on the Crow Search Algorithm to ensure reliable GMPP tracking of PV systems operating under partial shading. The objective is to demonstrate that CSA can effectively locate the true global maximum operating point where classical methods typically fail, thereby improving power extraction efficiency under difficult environmental conditions.

METHOD

The proposed method applies the Crow Search Algorithm as an MPPT strategy to determine the optimal operating voltage of the PV array under PSC. CSA is inspired by the intelligent behavior of crows in hiding and retrieving food, and it is characterized by strong exploration and exploitation capabilities, which are well suited for multimodal optimization problems such as the PV P–V curve under shading. In this approach, each crow represents a candidate operating voltage of the PV system. Through iterative position updates governed by awareness probability and flight length parameters, the population of crows searches the solution space to converge toward the global maximum power point.

Figure 1 illustrates the flowchart of the CSA applied to the PV system under partial shading, detailing the initialization, memory update, position update, and convergence process toward the GMPP.

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1: Initialization:
2: Set  $N = 20$ ,  $T_{max} = 20$ ,  $fl = 2$ ,  $AP = 0.1$ 
3: for  $i = 1$  to  $N$  do
4:   Randomly initialize  $V_i \in [V_{min}, V_{max}]$ 
5:    $M_i \leftarrow V_i$ 
6:   Evaluate  $P(V_i)$ 
7: end for
8: for  $t = 1$  to  $T_{max}$  do
9:   for  $i = 1$  to  $N$  do
10:    Randomly choose  $j \neq i$ 
11:    if  $rand > AP$  then
12:       $V_{new} \leftarrow V_i + fl \cdot rand \cdot (M_j - V_i)$ 
13:    else
14:       $V_{new} \leftarrow V_{min} + rand \cdot (V_{max} - V_{min})$ 
15:    end if
16:    Bound  $V_{new}$  within  $[V_{min}, V_{max}]$ 
17:    Evaluate  $P(V_{new})$ 
18:    if  $P(V_{new}) > P(V_i)$  then
19:       $V_i \leftarrow V_{new}$ 
20:    end if
21:    if  $P(V_{new}) > P(M_i)$  then
22:       $M_i \leftarrow V_{new}$ 
23:    end if
24:   end for
25: end for
26: return Best  $V^*$  corresponding to GMPP
  
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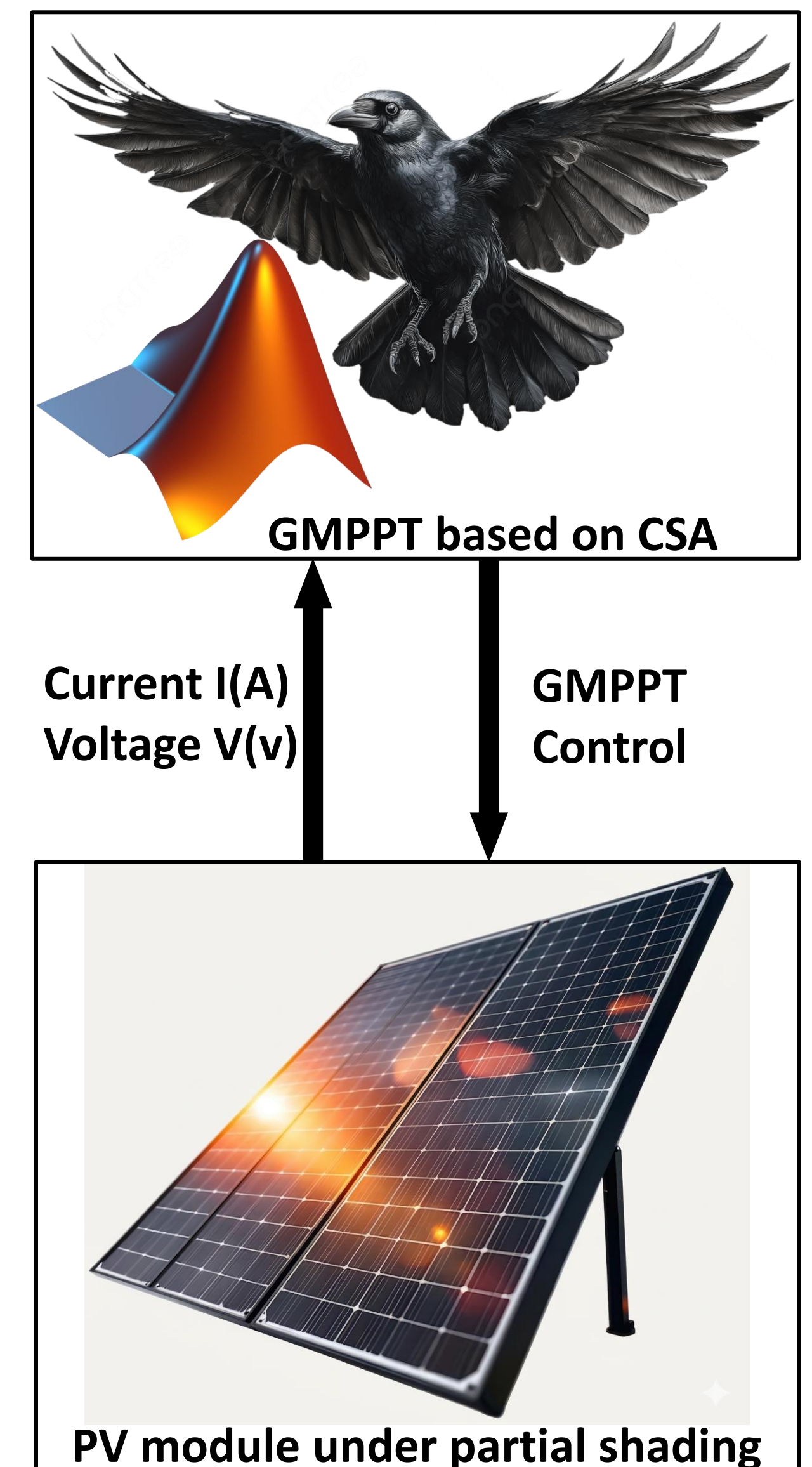


Figure 1: Flowchart of the Crow Search Algorithm applied to global MPPT under partial shading conditions

RESULTS & DISCUSSION

The effectiveness of the Crow Search Algorithm for GMPP tracking under partial shading is illustrated in Figure 2, which shows the evolution of candidate operating points over successive iterations on the PV P=f(V) curve.

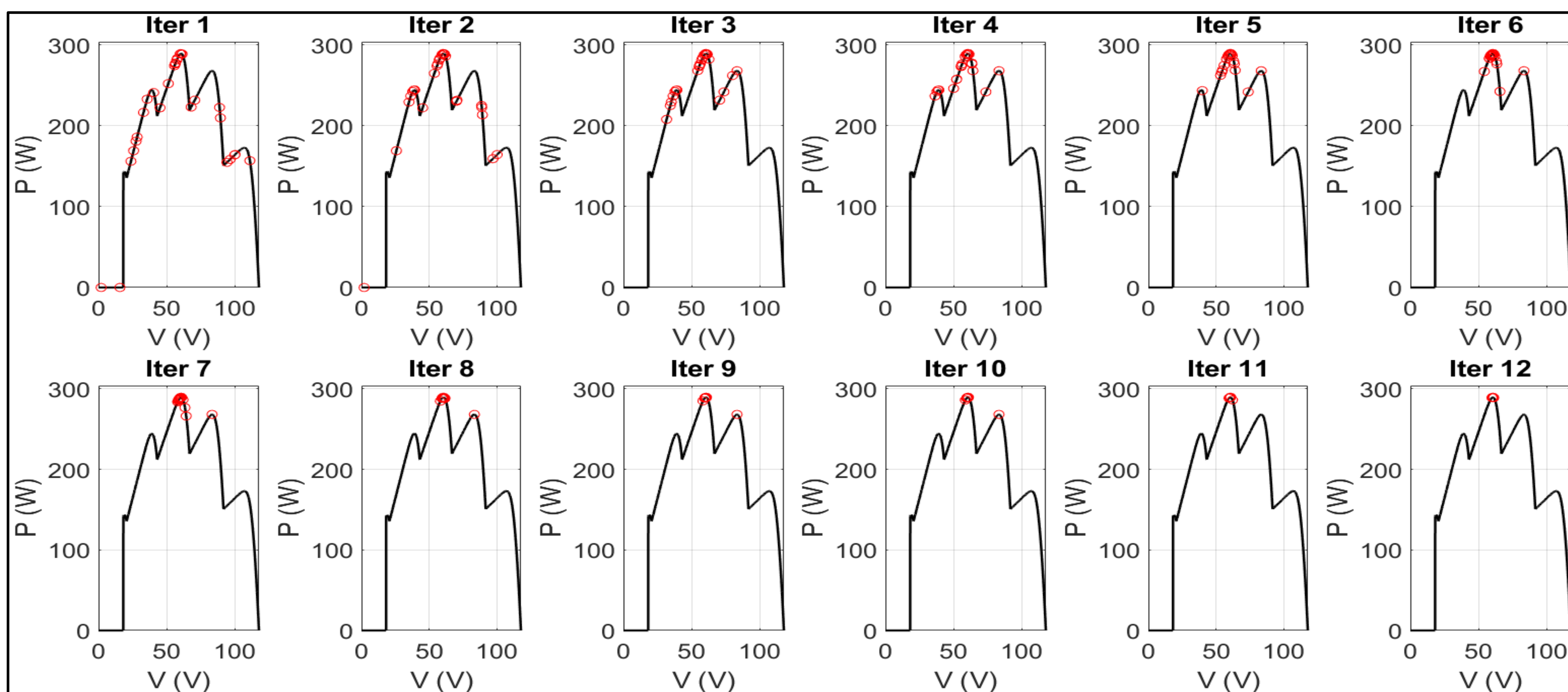


Figure 2: iterative convergence of the CSA toward the global maximum power point on the PV P–V curve under partial shading conditions.

At iteration 1, the crows (red markers) are randomly distributed over the entire voltage search space, covering different regions of the multimodal P–V characteristic where several local maxima exist. From iteration 2 to iteration 5, the population begins to concentrate around the most promising peaks, demonstrating the strong exploration capability of CSA while progressively discarding low-power regions. Between iteration 6 and iteration 9, a clear clustering behavior appears near the highest peak of the curve, indicating the transition from exploration to exploitation. The algorithm effectively avoids being trapped in secondary local maxima despite their proximity in power level. From iteration 10 to iteration 12, almost all candidate solutions converge to the same voltage corresponding to the global maximum power point (GMPP). This convergence confirms the stability and accuracy of CSA in identifying the optimal operating point under PSC. These results highlight the ability of CSA to handle the multimodal nature of the PV characteristic under shading and to reliably guide the search process toward the true GMPP, where classical MPPT methods typically remain stuck at local maxima.

CONCLUSIONS

This work presented a metaheuristic MPPT strategy based on the Crow Search Algorithm to ensure reliable global maximum power point tracking of photovoltaic systems operating under partial shading conditions. The iterative search process demonstrated how CSA efficiently explores the entire voltage space and progressively converges to the true GMPP without being misled by local maxima. The results confirm that CSA provides a robust and accurate solution for MPPT in challenging environmental conditions, improving power extraction capability compared to conventional techniques that are prone to local trapping. The proposed approach therefore represents an effective optimization-based alternative for enhancing the performance of PV systems under partial shading.

FUTUR WORK

Future work includes real-time validation, adaptive parameter tuning, and testing under dynamic irradiance to improve robustness and tracking speed.