# A novel simple GMPPT method based on probability distribution of global maximum power point under partial shading conditions

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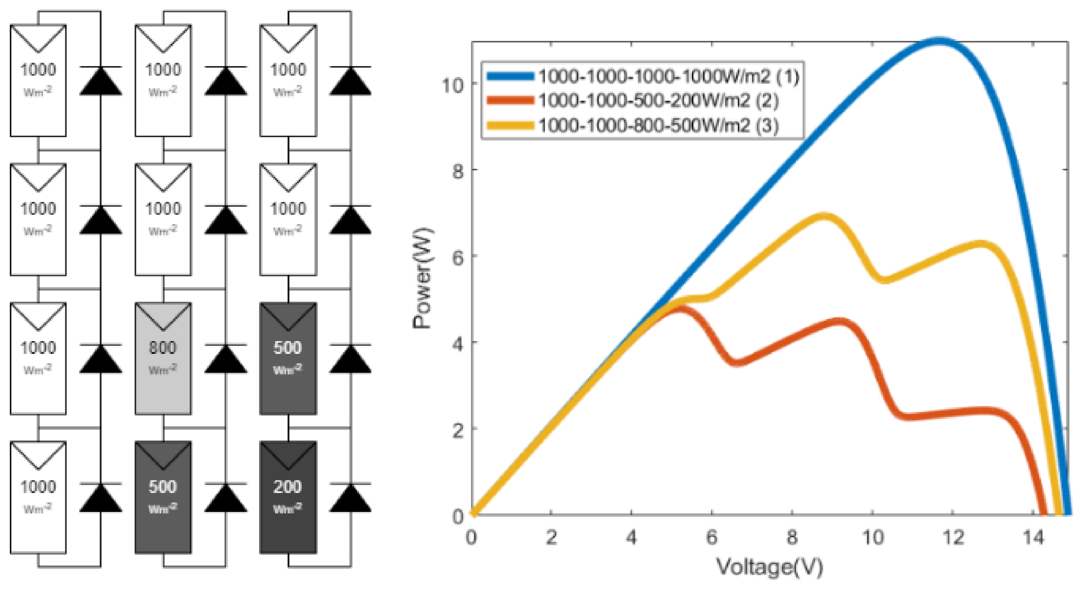
20th International Conference on Renewable Energies and Power Quality (ICREPQ'22)
Vigo (Spain), 27th to 29th July 2022
*Renewable Energy and Power Quality Journal* (RE&PQJ)
ISSN 2172-038 X, Volume No.20, September 2022

## 1 Context

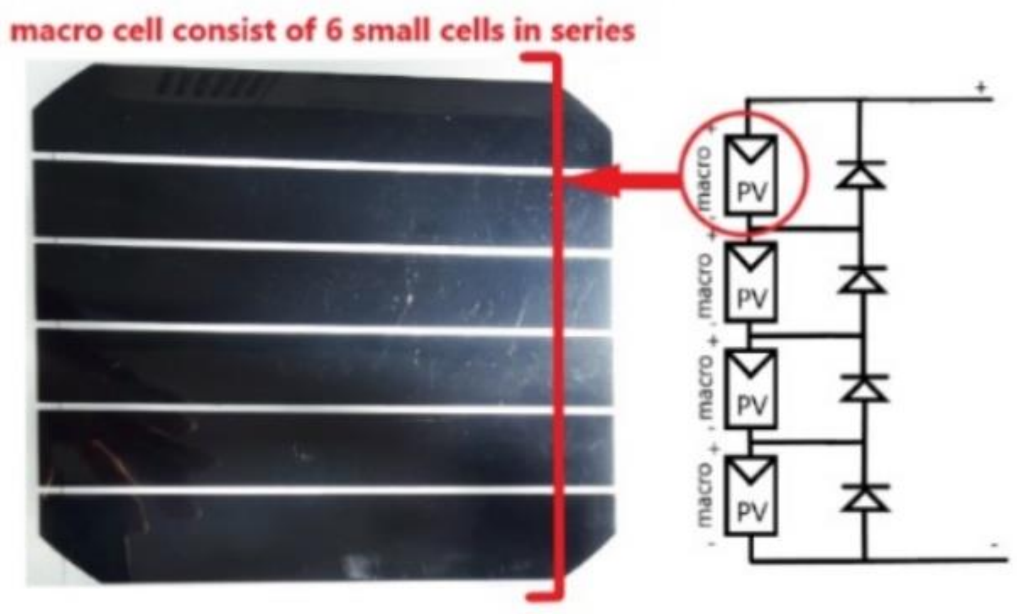
A photovoltaic (PV) array consisting of multiple cells in series with bypass diodes may exhibit multiple power peaks under uneven irradiation (Figure 1), therefore an algorithm is required to reach the global maximum power point (GMPP). Many methods have been proposed in the literature, but most are not easily implementable on a low-power microcontroller (µC). In our case, it is a PIC18F1320 in an autonomous embedded system, operating around 1-10W range.



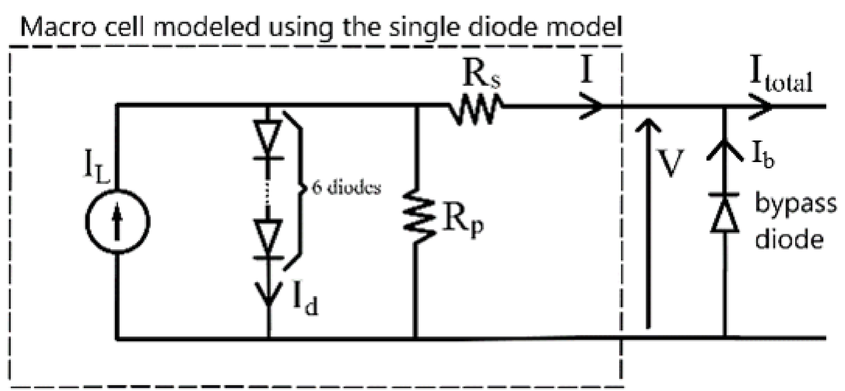

## 2 Objectives

For 4 PV modules in series with 4 bypass diodes :

- Present an exact method to solve of a PV array's power output
- Provide a probability distribution of where potential GMPP can be found on the PV array's operating range
- Simulate numerically a simple GMPPT based on the probability distribution information and evaluate its success rate.
- Simulate the algorithm in Simulink to verify its feasibility.




## 3 Solve the PV equation

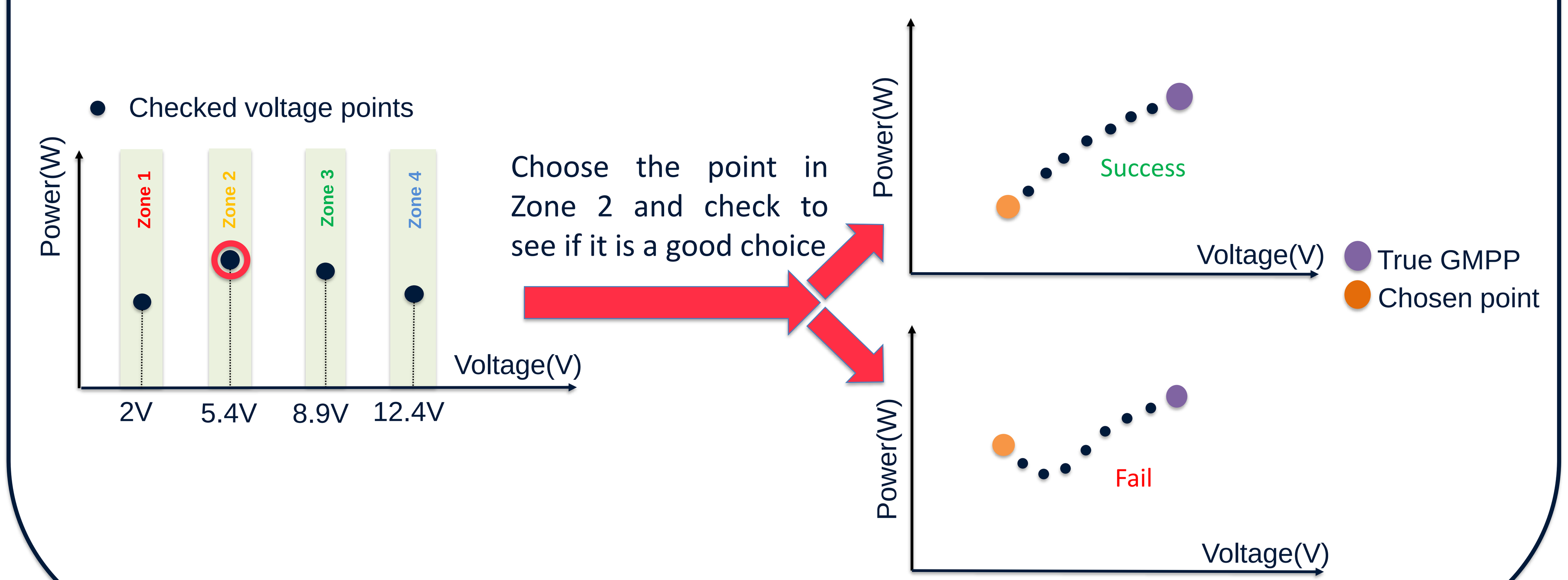



After solving the equations modeling the PV module, we have:

$$I = X - \frac{\text{Lambert}(KYR_s e^{KXR_s})}{KR_s} \text{ with } X = \frac{I_L + I_0 - \frac{V}{R_p}}{(1+\frac{R_s}{R_p})},\ Y = \frac{I_0 e^{KV}}{(1+\frac{R_s}{R_p})} \text{ and } K = \frac{q}{AkT}$$

## 4 Fast GMPPT from distribution

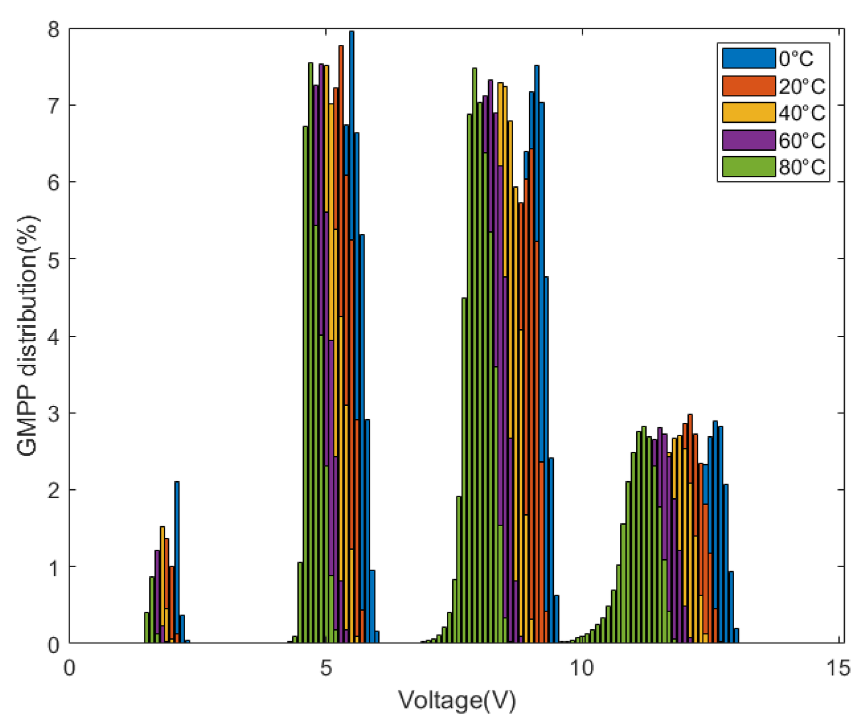
The distribution results shows that by limiting the algorithm to only 1 point per GMPP region, take the one with the highest power, and by assuming that the P&O that follows the initial search should be able to determine a MPP if the power gradient is monotonic, the simulation shows that a tracking efficiency of 93.64%. An example is shown below.




## 5 Probability distribution of GMPP

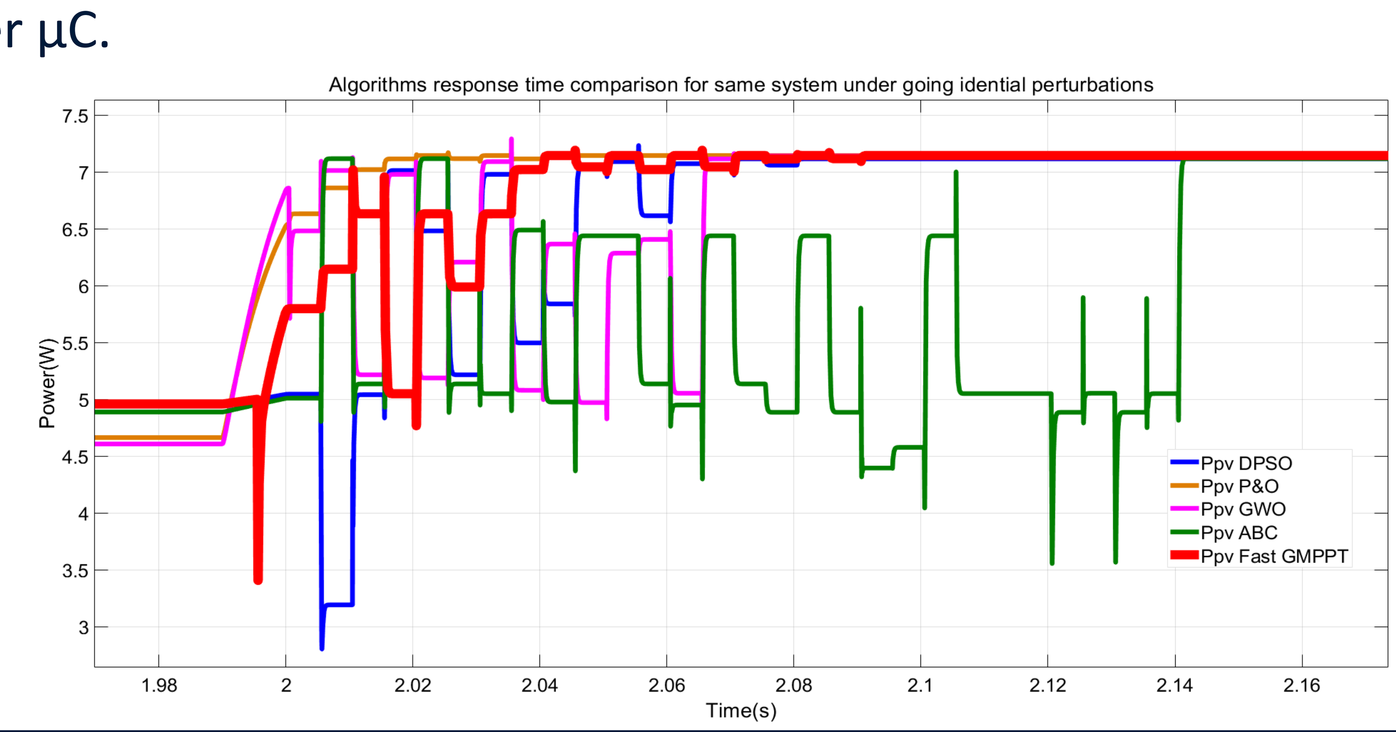
From the solved PV equations, we can quickly simulate a very large number of theoretical power output of our PV array. Optimizations such as reducing redundancy, parallel computing and limiting the use of computing intensive operations helped us achieve a staggering 9µs per array simulated (around 746000 times faster than using Simulink alone).

Varying the irradiation received by each PV module from 0 to 1000Wm$^{-2}$ in steps of 10Wm$^{-2}$ and the global temperature from 0°C to 80°C in steps of 20°C, we find the GMPP for each condition and register the voltage where GMPP occur. The resulting distribution shows that GMPP occur in distinct zones.




## 6 Simulation result

A MATLAB/Simulink model was developed to simulate our method and compare it to other lightweight algorithms. It shows that our method are at least competitive while being much easier to implement in a low-power µC.




## 7 Conclusion

Using efficient method to quickly simulate the power output of an array under a large amount of weather conditions, we plotted the distribution of the GMPP on the voltage range proving clear zone delineation and estimated that our proposed fast-tracking method can reach GMPP in 93.64% of the time. Simulink simulation result versus other lightweight algorithms shows promise and warrants further research on real hardware and weather conditions.