

Research Article

A photovoltaic system under partial shading

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ABSTRACT

Background: This project aims to study the influence of shading on a photovoltaic system.

Methods: This study examines two intelligent control algorithms to maximize power output, especially in shaded conditions. Specifically, we demonstrate how to apply two evolutionary algorithms to this control: the "particle swarm optimization method" and the "grey wolf optimization method." These algorithms were tested and evaluated.

Results: A comparison is made between a double MPPT system using PSO and GWO, and the best solution is identified.

Conclusion: The simulation results focus on a photovoltaic system that powers an electric vehicle while moving in realistic scenarios with partial shading conditions.

Introduction

Due to its availability and the good conversion factor, solar energy technology has advanced at an exponential rate in the last few years (1). As a renewable energy source, generation from solar energy eliminates pollution caused by traditional energy industries by lowering air novice emissions (2). Moreover, electricity generation from this resource is quite viable for a variety of uses. In particular, the rapid development of solar energy instruments gives a complete kit of tools that can be directly applied into the field of Electric Vehicles (EV) (3,4). Several studies have suggested that photovoltaic cells can be used to cover EVs' surfaces to store a significant amount of electricity in the storage system (5,6). This would increase EVs' autonomy, which will in turn increase the use of EVs. Some additional benefits are also associated to solar-powered Electric Vehicles (7,8). First, the load peaks may be reduced so that the grid management is easier. Second, a decrement of the costs of charging the EVs would also be perceived by the drivers.

In (9), researchers provided some statistics that prove that there is a huge free space to place photovoltaic (PV) cells in the car. As pointed out, these components can be used to help feed the car with electricity. It is possible to have 6 kW of electrical power in some buses or trucks with this kind of installation (10).

In order to benefit from this technology, the solar cells must be installed in a particular location on the vehicle to enhance the average autonomy of the vehicle. In the previously cited references, it is stated that the Audi car model can get around 600 W from solar equipment. If the EV model is pure electric, the PV cells can help to feed the vehicle with 1% of the total electric power when it is moving. In addition, the energy can be obtained while the EV is parked. It is proved that the PV solution is interesting for heavy trucks because there is more vacant area that can be used to generate renewable electricity. The PV system can provide 2% of their consumption when moving along a long road. However, the statistics are different in the city, as there are many

shading areas where the efficiency of the PV system may be affected. The way to estimate the energy return is challenging since it depends on the vehicle's relative situation compared to the sun's light and the presence of road obstructions. Because the car can quickly change from one type of shading scenario to another, obtaining the maximum amount of energy in all these conditions is quite tough. This is even more complex if we take into account that the efficiency of PV energy production mainly depends on the dynamic conditions associated to solar energy. The most relevant features are radiation, temperature, and the state of the PV field surface (dirt, deterioration). These factors directly influence its photon absorption and therefore affect the productivity of PV panels. In addition, the phenomenon of partial shading is one of the problems that impair the proper functioning of a PV plant. Partial shading is a non-uniform distribution of illumination on photovoltaic modules, which is due to several reasons. Indeed, there are two types of shading (11,12) The distant shade corresponds to the disappearance of the sun behind the horizon line. Alternatively, close shading is often due to unavoidable obstacles such as power lines, trees, neighboring buildings or dirt.

Methods

The control method that was found adaptable for this kind of problems is related to the PSO and GWO algorithms. To apply these algorithms, we need to define the functions and parameters for the proposed problem. The objective is to maximize the energy extraction from the PV cells installed on EVs, even when there are shadowing areas involved in the scenario to consider.

For the PSO algorithm, the function to optimize is expressed in Equation (1).

$$\max(Ppv) = f(x_{ij}^t, v_{ij}^{t+1}) \quad (1)$$

In the GWO, each wolf position corresponds to the duty cycle factor applied on the MPPT. Thus, the G_{max} represents the global best position of all of the wolves and P_{max} is the corresponding best position of the corresponding wolf. If no partial shading exists, the global best wolf best position and the local wolf best position will be the same. However, for the partial shading case, there is several (P_{max}) wolf best positions, and the global best position (G_{max}) will be related to the max of the best wolf position $G_{max} = \max (P_{max})$.

The proposed GWO algorithm aims to compensate for the limitations of conventional maximization algorithms, which cannot find the overall maximum, especially during a partial shading phenomenon. Regardless of the partial shading profile, this algorithm can find the maximum power point on the power-voltage characteristic of a photovoltaic system. Towards this goal, the objective function for this algorithm is defined as it is in Equation (2). α , β , Δ , ω , are specific equation in the GWO algorithm (17).

$$\max(P_{pv}) = f(\alpha, \beta, \Delta, \omega) \quad (2)$$

The proposed MPPT algorithm is based on the application of GWO to control the duty cycle. The expected consequence is that this will turn into decreasing the steady-state oscillations presented by the conventional MPP tracking algorithms. Consequently, the power loss due to oscillation is reduced, which increases the photovoltaic system efficiency.

For the implementation of GWO MPPT algorithm, duty cycle d is defined as a grey wolf. Therefore, the Equation (3) can be rewritten as follows:

$$d(k+1) = d(k) - A.d \quad (3)$$

The fitness function of the GWO algorithm is formulated to have the objective of function (4). It is for the two optimization algorithms.

$$P(d_j^k) > P(d_j^{k-1}) \quad (4)$$

where P represents the PV power, d is the duty cycle of the boost converter, j is the current grey wolves' number, and k is the iteration number.

The flowchart and the parameters of the PSO and GWO MPPT algorithms are detailed in Table 1, respectively.

Table 1. Parameter of the PSO and GWO MPPT algorithms.

	PSO	GWO
Inertia weight (w)	0.1	–
Personal Learning Coefficient $c1$	1.7	–
Global Learning Coefficient $c2$	1.5	–
Constant a	–	Self-adaption
Coefficient r_1 and r_2	–	Random numbers in (0,1)
Number of iterations N	100	100
Number of particles P	10	10
Sampling time	0.0001s	0.0001s
Initial duty cycle	0.4	

System of PV

A typical PV cell produces less than 2 W at about 0.5 V so that cells must be connected in series-parallel on a module to produce enough power (13). A PV array, is a group of several PV modules electrically connected in series (N_s cells) and in parallel (N_p columns) to generate the required current and voltage.

The voltage-current characteristic equation of a PV module becomes as follows:

$$I = N_p \cdot I_{ph} - N_p \cdot I_{sd} \left[\exp \left(\frac{q \left(\frac{V_{pv}}{N_s} + \frac{I \cdot R_s}{N_p} \right)}{K \cdot T \cdot n} \right) - 1 \right] - \frac{(N_p - V_{pv} + I \cdot R_s)}{R_p} \quad (5)$$

Figure 1 shows the proposed block diagram of the PV system. In this model. We include the intelligent MPPT algorithm (based on GWO and PSO) (14). The proposed algorithms aim to compensate for the limitations of conventional maximization algorithms, which cannot find the overall maximum, especially during a partial shading phenomenon. Regardless of the partial shading profile, it can find the maximum power point on the power-voltage characteristic (P_{pv}) of a

photovoltaic system. This characteristic is usually referred to as $P_{pv} = f(V_{pv})$ (15). The algorithm is applied to the semiconductor switch of the boost converter installed to connect the PV panels to the DC-link. Specifically, the duty cycle of this device is adjusted according to the output of the Intelligent MPPT algorithm. In our implementation, V_{out} is the voltage that will be used for feeding the battery with the required power for its charge (16).

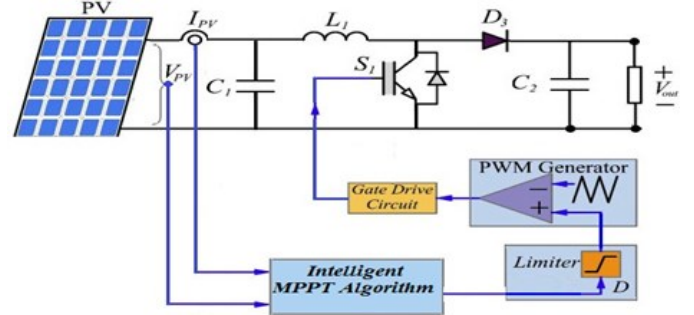


Figure 1. Block diagram of a PV system using an intelligent MPPT algorithm.

Results

The algorithms previously studied are applied to a PV system composed of 4 photo-voltaic modules. They are connected in a combination of serial and parallel.

Considering the size of the PV modules, this system could be implemented in electric vehicle application or even an isolated grid for feeding some isolating area using a solar energy. Some recharge stations can also benefit from this solution and the proposed method can improve energy yield.

The simulation bloc can be illustrated as it is Figure 2, all the PV cells are connected to the DC bus, which can give information about the global voltage and current, in relation to the solar radiation factor. Then the MPPT algorithm can extract the maximum of power using the PSO or the GWO algorithm. A DC converter is used for having information about the outputted power delivered to the load.

Discussion

Indeed, to compare the efficiency of MPPT PSO and GWO we considered four simulation tests so that a wide variety of conditions are modelled, Table 2, gives the maximum power, voltage and current parameters for each shading condition. During the first test, the irradiation was kept constant and uniform for the four modules (1000 W/m²). The second test is characterized by partial shading on two of the four modules of around 40%, represented in Figure 3. The partial shading on the two modules is varied in the order of 50% on the first and 20% for the second (500 W/m², 800 W/m², 1000 W/m², 1000 W/m²).

Table 2. PV characteristics study for a different type of shading.

	Pmpp (W)	Vmpp (V)	Impp (A)
First case of Partial shading	646.3	126.2	5.12
Second case of Partial shading	637.9	93.04	6.85

Conclusion

This work attempts to study and discuss two MPPT techniques based on two meta-heuristic optimization algorithms, i.e., PSO and GWO. These new techniques of MPPT overcome the problems of classic MPPT strategies (e.g., perturb and observe and incremental) when tracking the maximum power point, even in the presence of sudden changes of irradiation and shadows on the photovoltaic modules. The MPPT techniques studied show good behavior and better performance. A comparative study of simulation results for a different type of shading shows PSO-MPPT effectiveness compared to GWO-MPPT from the point of view of speed and oscillation during the transient state. In addition, a simulation test shows the efficiency of PSO MPPT versus GWO MPPT in terms of storage charge in the battery under uniform irradiation. As a future work, we would like to analyze how to adapt the algorithm's parameters (which are now constant) to the dynamic lighting conditions.

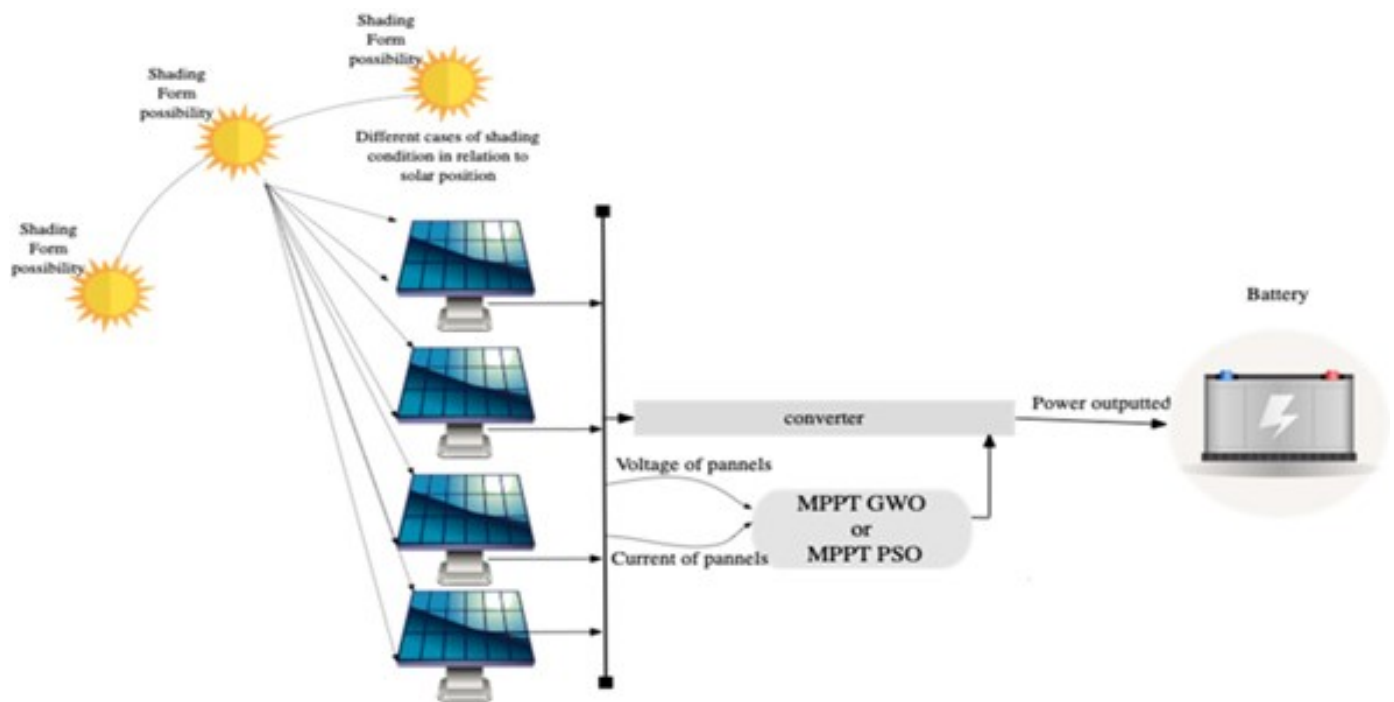


Figure 2. Overall system design in the simulation phase.

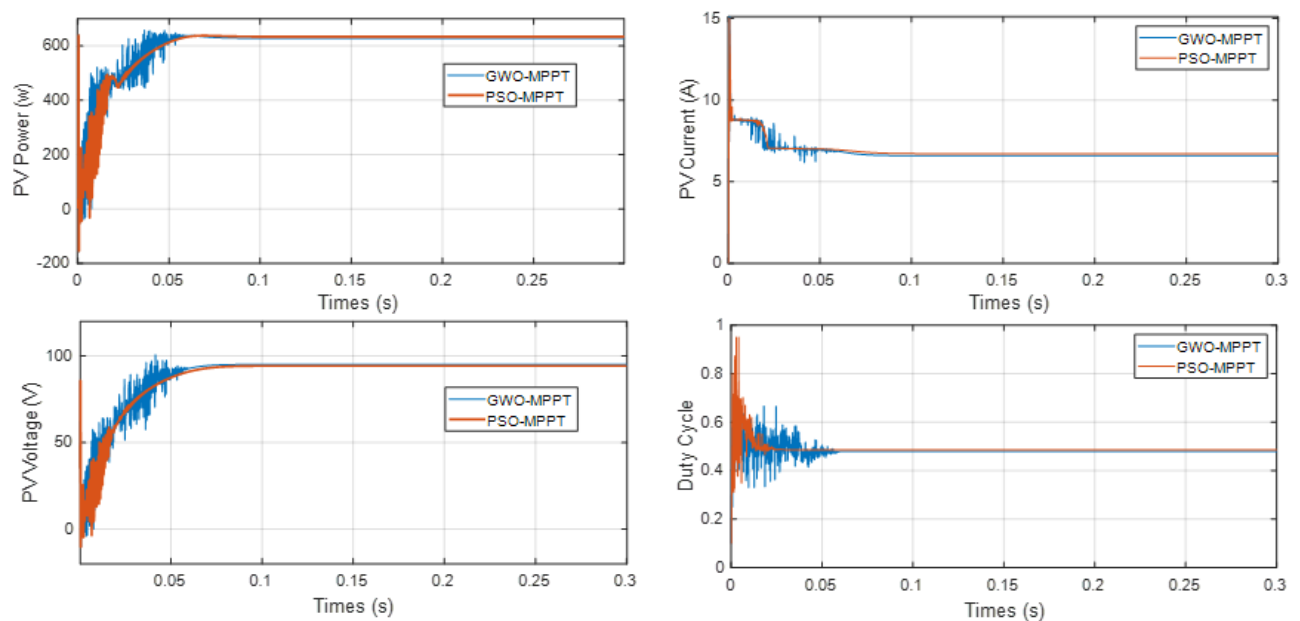


Figure 3. PV characteristics under partial shading: (500 W/m², 800 W/m², 1000 W/m², 1000 W/m²)

Competing interests

The authors declare no competing interest.

Authors contributions:

A Flah, L; yahya, , developed the research concept; and designed the data collection process; analysis of the data, and drafted the study reports. A. Flah provided academic guidance and continuous supervision, reviewed the study.

Data information:

No data to be share

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References

1. Xie, W.T.; Dai, Y.J.; Wang, R.Z.; Sumathy, K. Concentrated solar energy applications using Fresnel lenses: A review. *Renew. Sustain. Energy Rev.* 2011, 15, 2588–2606. <http://doi.org/10.1016/j.rser.2011.03.031>
2. Mokarram, M.; Mokarram, M.J.; Khosravi, M.R.; Saber, A.; Rahideh, A. Determination of the optimal location for constructing solar photovoltaic farms based on multi-criteria decision system and Dempster–Shafer theory. *Sci. Rep.* 2020, 10, 8200. (CrossRef)
3. Lv, Z.; Qiao, L.; Cai, K.; Wang, Q. Big Data Analysis Technology for Electric Vehicle Networks in Smart Cities. *IEEE Trans. Intell. Transp. Syst.* 2021, 22, 1807–1816. (CrossRef)
4. Mohamed, N.; Aymen, F.; Ali, Z.M.; Zobaa, A.F.; Aleem, S.H.E.A. Efficient Power Management Strategy of Electric Vehicles Based Hybrid Renewable Energy. *Sustainability* 2021, 13, 7351. (CrossRef)
5. Habib, A.K.M.A.; Hasan, M.K.; Mahmud, M.; Motakabber, S.M.A.; Ibrahimya, M.I.; Islam, S. A review: Energy storage system and balancing circuits for electric vehicle application. *IET Power Electron.* 2021, 14, 1–13. (CrossRef)

6. Flah, A.; Majed, A.; Bajaj, M.; Naveen, K.S.; Mishra, S.; Sharma, S.K. Electric Vehicle Model Based on Multiple Recharge System and a Particular Traction Motor Conception. *IEEE Access* 2021, 9, 49308–49324. <http://doi.org/10.1109/ACCESS.2021.3068262>
7. Arun, P.; Mohanrajan, S. Effect of Partial Shading on Vehicle Integrated PV System. In *Proceedings of the 2019 3rd International Conference on Electronics, Communication and Aerospace Technology (ICECA)*, Coimbatore, India, 12–14 June 2019; <http://doi.org/10.1109/ICECA.2019.8821888> pp. 1262–1267.
8. Mobarak, M.H.; Kleiman, R.N.; Bauman, J. Solar-Charged Electric Vehicles: A Comprehensive Analysis of Grid, Driver, and Environmental Benefits. *IEEE Trans. Transp. Electrification* 2021, 7, 579–603. (CrossRef)
9. Al-Shammaa, A.A.; Stocker, A. A Novel Method for Event Detection using Wireless Sensor Networks. In *Proceedings of the ICCSW, London, UK, 20–21 September 2018*. <http://doi.org/10.4230/OASIS.ICCSW.2018.9>,
10. Kraiem, H.; Flah, A.; Mohamed, N.; Alowaidi, M.; Bajaj, M.; Mishra, S.; Sharma, N.K.; Sharma, S.K. Increasing Electric Vehicle Autonomy Using a Photovoltaic System Controlled by Particle Swarm Optimization. *IEEE Access* 2021, 9, 72040–72054. (CrossRef)
11. Lin, G.; Bimenyimana, S.; Tseng, M.-L.; Wang, C.-H.; Liu, Y.; Li, L. Photovoltaic Modules Selection from Shading Effects on Different Materials. *Symmetry* 2020, 12, 2082. (CrossRef)
12. Picault, D.; Raison, B.; Bacha, S.; de la Casa, J.; Aguilera, J. Forecasting photovoltaic array power production subject to mismatch losses. *Sol. Energy* 2010, 84, 1301–1309. (CrossRef)
13. Chang, W.J.; Lee, K.-H.; Ha, H.; Jin, K.; Kim, G.; Hwang, S.-T.; Lee, H.-M.; Ahn, S.-W.; Yoon, W.; Seo, H.; et al. Design Principle and Loss Engineering for Photovoltaic-Electrolysis Cell System. *ACS Omega* 2017, 2, 1009–1018. (CrossRef)
14. Dashtdar *et al.*, “Improving the power quality of island microgrid with voltage and frequency control based on a hybrid genetic algorithm and PSO,” *IEEE Access*, vol. 10, no. October, pp. 105352–105365, 2022.
15. Liu, Y. Luo, J. Huang, and Y. Liu, “A PSO-based MPPT algorithm for photovoltaic systems subject to inhomogeneous insolation,” in *The 6th International Conference on Soft Computing and Intelligent Systems, and The 13th International Symposium on Advanced Intelligence Systems*, 2012, pp. 721–726.
16. M. Nazelan, M. K. Osman, N. A. Salim, A. A. A. Samat, and K. A. Ahmad, “PSO-based neural network controller for speed sensorless control of PMSM,” in *2017 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 2017, pp. 366–371.
17. A. Saxena, A. Sharma, and S. Shekhawat, “Parameter extraction of solar cell using intelligent grey wolf optimizer,” *Evol. Intell.*, 2020.