Electric vehicle charging using roof top photovoltaic controlled with new hybrid optimization technique

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ABSTRACT

In this decade, electric car technology has advanced at a breakneck pace. People are also using electric vehicles more since they are more inexpensive. Electric car charging is one of the issues that most sectors confront, as there are many cities in India where charging stations have yet to be established. In this paper, an innovative approach for charging a vehicle while on the move is presented, utilizing the solar panels on the vehicle's roof. The panels collect energy from the sun and use it to charge the vehicle's battery. Even when the vehicle is driving down the road, this happens. Partial shading is a concern for solar panels when travelling on the road. In this paper, a new hybrid optimization technique combining grey wolf optimization and crow search algorithms (GWO-CSA) is employed to compare an electric car model to the traditional particle swarm optimization (PSO) approach. The MATLAB simulation results demonstrate the vehicle's performance and tracking efficiency.

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1. INTRODUCTION

Several manufacturers have introduced energy-efficient and cost-effective electric vehicles over the last decade. Developing countries such as India, on the other hand, continue to be underserved. In the near future, there may be a substantial demand for charging stations or alternative charging methods. Solar energy has recently risen to prominence as one of the most straightforward and ecologically friendly energy sources [1]. The tracking of solar panels' maximum power points has been the subject of numerous articles. In partially shaded circumstances, maximum power tracking for Electric Vehicle (EV) on-the-go charging is a big challenge. Furthermore, a hot spot in the solar cells leads in power loss due to the partially shaded conditions. Several papers explain methods to overcome this partially shaded state utilising optimization algorithms and intelligent strategies, as well as reconfiguring solar panels or cells. The solutions to this problem are described in the following articles.

The solar cells housed within the panels are examined by Bishop [2]. Present value Net is a Pascal programme that simulates the electrical behaviour of solar cell interconnection networks and was developed at the European Communities' Joint Research Centre in Ispra. The software creates three-quadrant solar cell current–voltage (I–V) curves, combines them to get the next I–V curve for any interconnection circuit, and determines the operating point of each circuit element based on user-defined operating parameters. In the PSpice environment, offers a method for simulating and modelling partially shadowed solar cells and Photo-Voltaic (PV) modules [3]. When the modules are covered or broken, bypass diodes are used to minimise power consumption and prevent cells from running too close to the avalanche zone. Dorado *et al*. [4] looks at the operation of a photovoltaic array. These qualities show that when the PV panels are shaded, they contain several peaks, as stated in [2]-[4]. Villa *et al*. [5] investigates the available interconnections between modules in a shaded solar field and how they effect power generation to remedy this issue. As a result, empirical connection laws are provided to show a strong relationship between photovoltaic module interconnections and output.

Sharma and Agarwal [6] offers a revolutionary distributed maximum power point tracking (DMPPT) technique that is both easy to use and extract, resulting in precise maximum power point tracking (MPPT). Each photovoltaic module is resonated by a different arrangement of the shunt-connected direct control DC-DC converter in this setup. Based on shade detection and the trend of slopes out of each segment of the curve, Gosumbonggot and Fujita [7] provides a global maximum power point tracking technique (GMPPT). Mathematical equations and procedures are provided in their work entirety. Models based on observable weather data are used in both short-term and long-term study. Mahto *et al*. [8] covers topologies for PV panels such as total cross-tied, bridge link, and honeycomb to minimise the effect of partial shade. Based on the one-diode equivalent circuit of a PV cell and mathematical breakthroughs addressed in the literature [9], the authors provided a simple and accurate model of solar arrays working in partial shadowing situations. The array status evaluation is crucial for ensuring the safe operation of large-scale solar power plants, as it might cause partial shadowing to become more severe. After that, they discovered that a number of indicators properly reflect the state of solar panels. The k-means clustering algorithm [10] was used to build the performance assessment method. The technique detects the voltages and irradiances of solar cells or panels and performs a reconfiguration. In mismatch situations, such as partial shade, charge redistribution through a switched capacitor achieves power balance [11]. Hot spot identification is carried out. It has been proposed a simple method for determining hot zones [12]-[14]. Furthermore, an effective technology is used to prevent hot spots on the panels. The hot spot detection approach is based on the equivalent DC impedance of the panel's strings, which has useful qualities for identifying hot spots.

The PV array is partially shaded, and other challenges related to the vehicle's solar panel integration are discussed in [15]. The articles also go into the proposed solutions for partial shaded situations, which include meta-heuristics and intelligent techniques. In the grid-connected solar system, a comparison of the Perturb and Observe approach with the particle swarm optimization (PSO) algorithm under partial shadow circumstances is presented in articles [16], [17]. Using an improved pattern search method, this article [18] proposes a method for MPPT of a photovoltaic panel array with partial shadowing. The Firefly Algorithm (FA) [19] is a control method for switching patterns in non-homogeneous shading profiles that tracks the highest global peak of power created by a large number of switching patterns. Srinivasan *et al*. [20] introduces the meerkat optimization algorithm (MOA), a revolutionary, intelligent, bio-inspired algorithm capable of locating the worldwide power peak and ensuring maximum power supply. Using simulated annealing (SA), Lyden and Haque [21] provides a technique for tracking the GMPPT of partially shaded photovoltaic (PV) systems. Both the commonly used perturb and observe MPPT methodology and the particle swarm optimization method are compared to the new GMPPT strategy. Abo-Khalil *et al*. [22] employs an Opposition-based learning Firefly Algorithm (OFA) to improve the performance of solar systems under both uniform irradiance changes and partial shade conditions as an alternative to typical PV MPPT techniques. The chimp optimization algorithm (ChOA), a metaheuristic algorithm inspired by chimps' innate social behaviour, Nagadurga *et al*. [23] to track the MPPT of solar PV strings. Prasad and Thiyagarajan [24], kinetic gas molecular optimization is discussed in terms of MPPT and the maximum number of iterations kinetic gas molecule optimization (KGMO). This differs from ant colony optimization (ACO). ACO takes more cycles than the KGMO technique to attain the necessary partially shadowed irradiation conditions. Kraiem *et al*. [25] compares the performance of the PSO and grey wolf optimization algorithms in the battery management of a solar power system. The multi-objective function is used to track MPPT in [26], and the results are compared to single and multi-objective tracking.

PV roof-top on electric vehicles with 2 kW panels and on-the-go charging is proposed in this article. A hybrid optimization approach has been devised to extract enough power for charging. For optimal power efficiency, an electric vehicle model using the hybrid optimization algorithm of grey wolf optimization and crow search algorithm (GWO-CSA) was developed and compared to the traditional particle swarm optimization (PSO) algorithm. MATLAB Simulink is used to analyse the extraction of maximum power and the vehicle's performance.

2. METHOD

The model provided in this research is the proposed system depicted in Figure 1. It includes 5 PV panels connected by retractable metal bars that are hinged vertically to the automobile model's roof surface.

The panels can be moved around and detached from the roof. For clarity, the connecting wire is not shown in Figure 1. The battery and charger are shown in Figure 2, with the motor drive acting as a load on the battery. The PV panels provide the input to the charger, and the PV panels output the required voltage based on the irradiation. The voltage and current measured at the PV input terminals are V_{pv} and I_{pv}. The Li-on battery is connected to the on-the-go charger. The inverter operates the permanent magnet brushless DC (PMBLDC) motor, which is connected to the battery. The reference voltage is predicted using the GWO-CSA or PSO algorithm based MPPT algorithm. And for constant current charging, the PWM was generated based on the present reference generation.

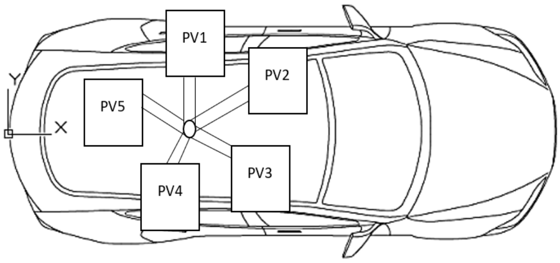

Figure 1. Proposed on-the-go charger car model

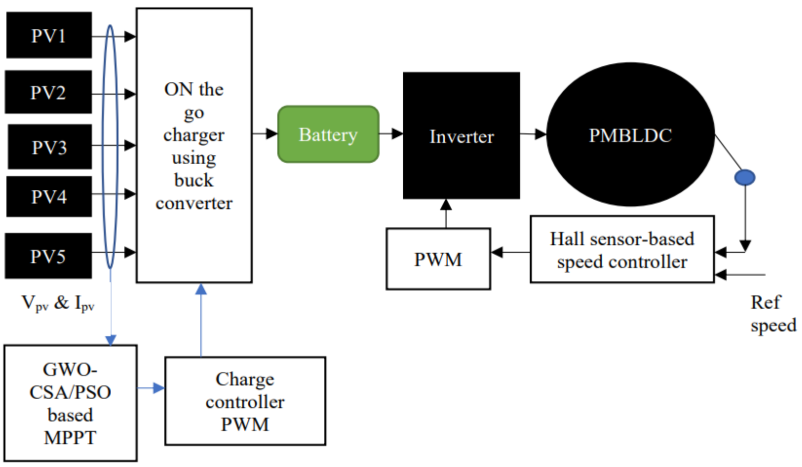

Figure 2. Proposed on the go charger model with battery and PMBLDC motor connected

2.1. Problem formulation

The following multi-objective equation is used to determine the most optimal duty cycle for on-the-go EV charger under partial shaded condition. It is necessary to maximize power. As an example, the objective function with constraint can be represented as (1),

Maximize,

$$F\left(V_{ref}\right) = \frac{\sum_{i=1}^{n} P}{n} \tag{1}$$

With inequality constraints,

$$V_{ref\ min} \leq V_{ref} \leq V_{ref\ max} \tag{2}$$

here,

- F–fitness function
- V_{ref}–reference voltage for MPP
- P–PV power
- n–Sampling time count

2.2. PSO algorithm

Swarm optimization is one of the simple algorithms to implement, which is made of the food searching behavior of the fishes. And this PSO algorithm is going to be compared with the proposed hybrid GWO-CSA algorithm for performance analysis of the on-the-go EV charger. Here the PSO algorithm is used to for the identification of optimal duty cycle. Algorithm flow is given in the Figure 3.

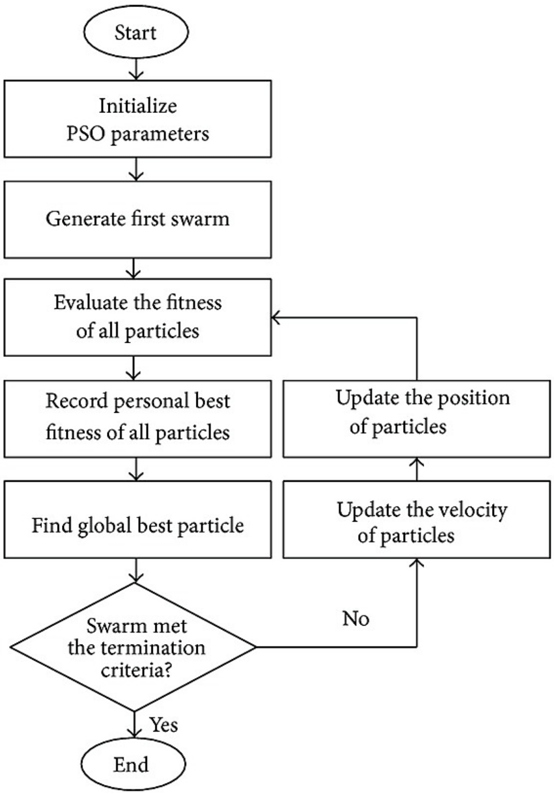

Figure 3. PSO flowchart

Velocity of PSO algorithm is given in (3),

$$V_j(i) = V_j(i-1) + c_1 r_1 \left[P_{bestj} - X_j(i-1)\right] + c_2 r_2 \left[G_{best} - X_j(i-1)\right] \tag{3}$$

where, $j = 1,2, \dots, N$
here,

$c1, c2$ *are cognitive and social learning rates* (*used value is* 2)
$r1, r2$ *are uniformly distributed randoms in range* 0 *and* 1

Position update as shown in (4).

$$X_j(i) = X_j(i-1) + V_j(i) \tag{4}$$

Here the particles (X) are the generator values and the fitness which is given in (1) is power maximization. The global best value is identified using the PSO algorithm. The final global best is carried again to the next iteration and the flow continues.

2.3. GWO-CSA algorithm

Individually, both the grey wolf and crow search algorithms perform admirably. Gray wolf achieves rapid convergence, whereas CSA achieves a 100% success rate. The features of both the algorithms are combined to get better performance. This hybrid GWO-CSA algorithm is going to be implemented in this paper. The control variable X_α, X_β *and* X_δ are the V_{ref} in this case. Figure 4 depicts the pseudocode. The random generating function is r_i. AP is the awareness probability. fl_i is the flight length. m_i is the dash line.

Initialize the V_{ref} as the gray wolf position
Initialize Iteration (a), coefficient vector (A and D) and probability (P_a)

Set the $X_\alpha, X_\beta, X_\delta$ accordind to the initial fitness
t=1
while (t<Max)
for each wolf
Update the position by $X(t+1) = (X_1 + X_2 + X_3)/3$
End for
Update a, A and C
Compute the fitness of each search agents in the pack
Update the $X_\alpha, X_\beta, X_\delta$
For $X_\alpha, X_\beta, X_\delta$
Update the position by Equation $x_i(t+1) = x_i(t) + r_i \times fl_i(t) \times (m_i(t) - x_i(t))), i = 1,2, \dots, n$
If random number > AP
Random change wolf's position
Compute the fitness and update it according to fitness
t=t+1
end while
Output X_α

Figure 4. Pseudocode for GWO-CSA

3 RESULTS AND DISCUSSION

According to the block schematic, the PV panels are linked. The solar PV is connected to the on-the-go charger, which is connected to the battery. The battery powers the PMBLDC motor, which is controlled by the hall sensor. Four cases are examined in this article. Irradiation between the PV panels in the first case is differed by 100 watts per square meter. PV1 generates 1000 watts per square meter, PV2 generates 900 watts per square meter, PV3 generates 800 watts per square meter, PV4 generates 700 watts per square meter, and PV5 generates 600 watts per square meter. In case 2, PV1 and PV2 generates 1000 watts per square meter, PV3 and PV4 generates 900 watts per square meter, and PV5 generates 800 watts per square meter. In case 3, PV1 and PV2 generates 700 watts per square meter, PV3 and PV4 generates 500 watts per square meter, and PV5 generates 400 watts per square meter. In the for case, PV1 generates 800 watts per square meter, PV2 and PV3 generates 600 watts per square meter, PV4 and PV5 generates 400 watts per square meter.

The Figure 5 depicts the Power and Voltage (P-V) curves for Case 1 with the values of power and voltage. The P-V curves of Case 2 are then shown in Figure 6. The P-V curves with P and V values of Case 3 are shown in Figure 7. Case 4 with P and V values are depicted in Figure 8. The corresponding PV curves of each case is represented with the X and Y axis marker. The voltage axis is on the X axis, and the power axis is on the Y axis. The monitored power comparison between PSO and GWO-CSA is shown in Table 1. The specified reference voltage comparison is shown in Table 2. It can be observed from table quantitatively that the GWO-CSA performs better in all conditions and extracts a lot of PV electricity.

The voltage reference error comparison using PSO and GWO-CSA is shown in Figure 9. The tracking efficiency comparison with PSO and GWO-CSA is shown in Figure 10. The results demonstrates that the voltage regulation in GWO-CSA is better, and the efficiency in the suggested system is also better. In all the four cases, the state of charge of the battery is shown in Figure 11.

Table 1. Tracked power comparison

Cases	Actual	PSO	GWO-CSA
Case 1	1801	1791.6	1792.1
Case 2	2348	2323.9	2328.45
Case 3	1116	1106	1109.63
Case 4	1139	1135.7	1135.8

Table 2. Selected reference voltage comparison

Cases	Actual	PSO	GWO-CSA
Case 1	93.45	93.506	92.2592
Case 2	91.13	89.348	89.8026
Case 3	71.1	71.932	70.7502
Case 4	91.51	89.803	89.3475

The battery's state of charge is maintained at 50% initial charge. The battery is depleting from 50% without the on-the-go charger. However, the on-the-go charger improves the battery's state of charge (SOC) in all four cases. The voltage of the battery is shown in Figure 12 in all four cases. As can be seen, the voltage levels vary depending on the power level. The voltage is lower when the battery is not charged. In all four5 cases, the reference current of the battery is shown in Figure 13. When the charger is not attached, the current is negative. When there is a lot of electricity available from PV, the charge current is high. When there isn't as much power available from PV, the charge current is lower. As a result, the on-the-go charger performed well in all the cases. With the PMBLDC motor operated by the inverter and hall sensor-based speed regulation, the battery is fully charged. The speed of the machine shaft is depicted in Figure 14. From this result it is observed that the dynamics of PV panels is not having much impact on the speed of the motor.

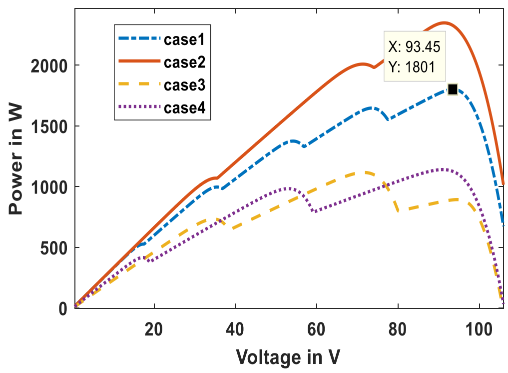

Figure 5. PV curves of Case 1: with 1000, 900, 800, 700, 600 W/m^2 irradiance

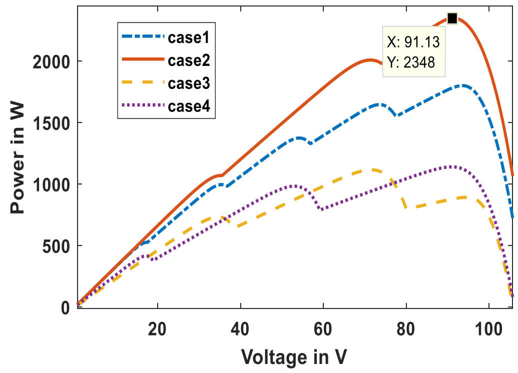

Figure 6. PV curves Case 2: with 1000, 1000, 900, 900, 800 W/m^2 irradiance

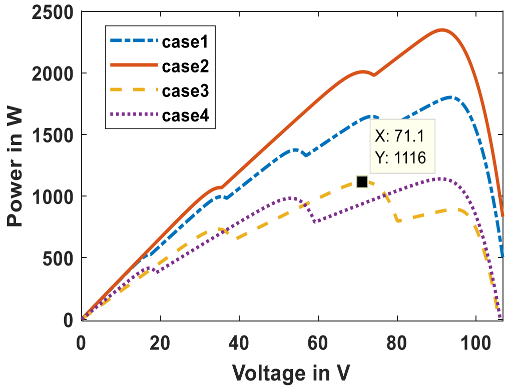

Figure 7. PV curves of Case 3: 700, 700, 500, 500, 300 W/m^2 irradiance

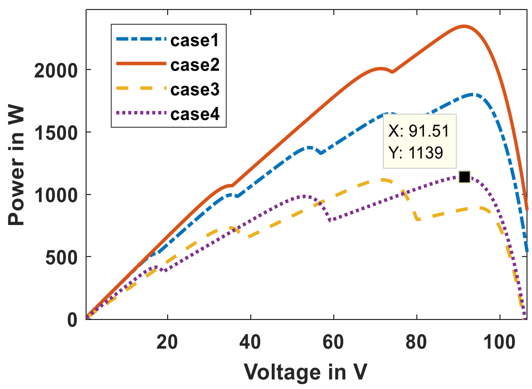

Figure 8. Case 4: 800, 600, 600, 400, 400 W/m^2 irradiance

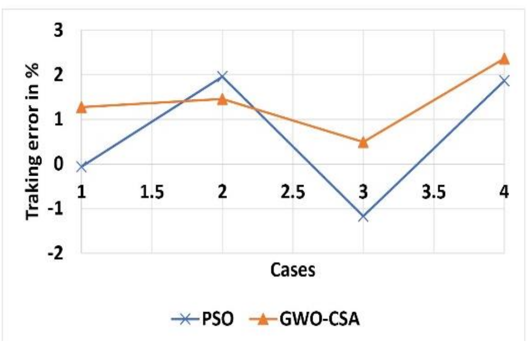

Figure 9. Voltage reference error comparison with PSO and GWO-CSA

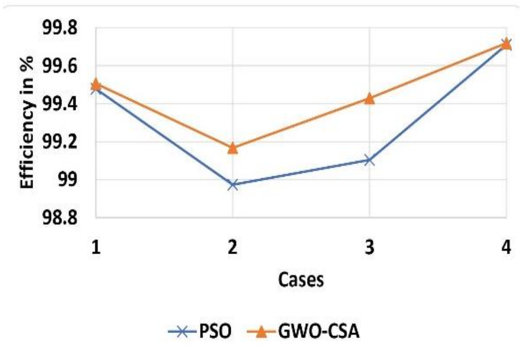

Figure 10. Tracking efficiency comparison with PSO and GWO-CSA

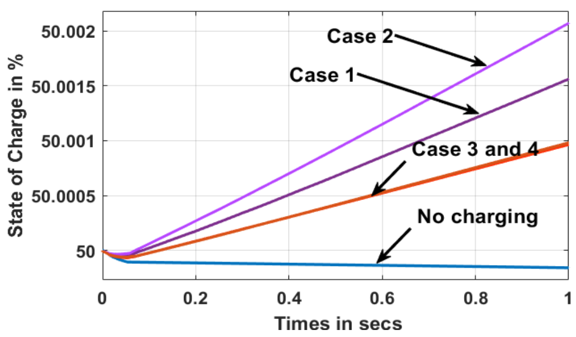

Figure 11. State of charge of battery in all the cases

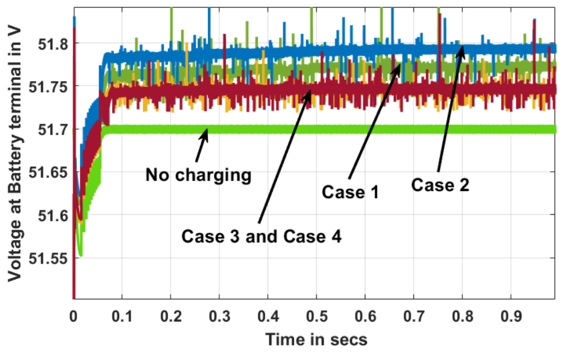

Figure 12. Voltage of battery in all the cases

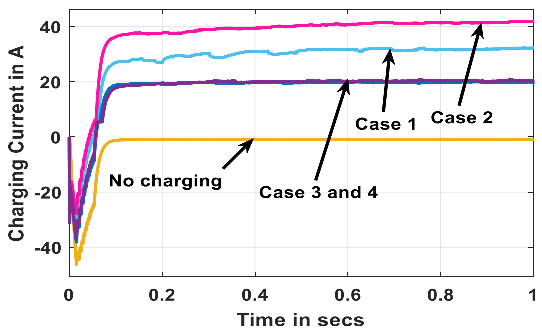

Figure 13. Reference current of battery in all the cases

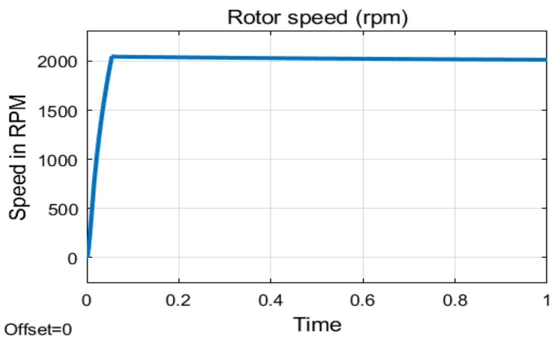

Figure 14. Shaft speed of the motor

4 CONCLUSION

The hybrid optimization algorithm of GWO-CSA is developed and programmed for charging of EV using on-the-go Roof-top PV charger. This is quite useful for GMPPT tracking. The result shows that the PMBLDC motor performs well even when the battery is being charged at the same time. Due to this proposed hybrid GWO-CSA algorithm, the PV power results are likewise satisfactory. The numerous cases demonstrate the on-the-go charger's dependability. The results given in the table for all the four cases shows that the GWO-CSA algorithm outperforms the PSO algorithm. The speed regulation of the PMBLDC motor in the on-the-go EV charger is better even under partial shaded condition of PV panels.

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