Photovoltaic-grid Complementary Electric Charging System Based on Whale Optimization Algorithm

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Abstract. This paper proposes a photovoltaic-grid complementary electric vehicle charging system based on whale optimization algorithm, including control part, traditional electric energy and photovoltaic energy supply part and electric vehicle charging equipment part. The electric vehicle is charged by the complementary power supply mode of photovoltaic energy and traditional grid power. The control system uses the whale optimization algorithm to dynamically plan the use of the charging equipment in different periods of time to optimize the utilization of photovoltaic and grid power. The photovoltaic-grid complementary electric charging system based on the whale optimization algorithm can effectively improve the user's satisfaction with the charging of electric vehicles, plan the utilization of new energy and grid energy, realize the economical efficiency of energy utilization, and reduce the energy use cost.

Introduction

The microgrid composed of new energy sources has access to large power grids with high reliability and meeting the demand for load growth. There is a real-time difference between the traditional grid electricity price and the new energy generation price[1]. For the current energy management in the microgrid, it is usually an offline optimization problem planned in the past. The energy and load cannot be accurately predicted, which makes the planning optimization impossible[2-4]. The architecture design of the microgrid only corresponds to a single energy form processing. Because the optimization target planning is not accurate enough, the coordination and unification of the hybrid energy scheduling control cannot accurately solve the problem. The new intelligent group algorithm can realize real-time planning and coordinate the scheduling of hybrid energy[5-7]. It is proposed to use the whale optimization algorithm to turn the traditional charging pile powered by the grid system into a photovoltaic-grid complementary power supply. Real-time control of traditional grid power and photovoltaic energy according to different electricity prices. When the grid electricity price is higher than the photovoltaic power price, the photovoltaic energy is used, and the photovoltaic energy is sold to the grid; when the photovoltaic energy price is lower than the grid price, the grid energy is used. It can reduce the cost of electricity and save costs[8-9].

Principles of Whale Optimization Algorithm Based on the Whale Optimization Algorithm

The Whale Optimization Algorithm (WOA) is an intelligent optimization algorithm proposed by Seyedali Mirjalili and Andrew Lewis in 2016 based on the humpback behavior of humpback whales. The algorithm randomly generates the initial solution and performs iterative optimization according to the humpback whale predation process, and finally obtains the approximate optimal solution[10].The photovoltaic-grid complementary electric vehicle charging system, by counting the data of the user charging for a period of time (time window), obtains the charging law to optimize the control of photovoltaic energy and grid energy. The whale algorithm can process data through fast convergence, obtain high-precision target values, and require fewer parameters to adjust. The device can optimize the utilization of photovoltaic energy and grid energy, and achieve more accurate scheduling control of energy.

The whale optimization algorithm is as follows: Firstly, the charging user can see the number of currently charged vehicles in the charging site, the number of remaining charging piles and related power information through the Internet platform, and make an appointment for charging. At the same time, the user can score satisfaction on the platform (out of 10 points, the score is greater than 6 is satisfactory, the remaining is not satisfied), and the processor collects current user satisfaction as an indicator of control. After the user performs the reservation charging, the reserved user charging power is collected for a period of time as the constraint condition of the whale algorithm, that is, the predicted total power consumption *P*t. The PV power generation *P*i, real-time PV price *C*w, real-time grid electricity price *C*e and other variables generated by different light intensity predicted by the local day, determine the relevant variable range, narrow the optimization range of the whale algorithm, and then use the whale algorithm to obtain economic optimal solution.

The whale algorithm includes wrap-around predation, bubble net attack, and search predation. The mathematical models are as follows:

Wrap-around predation: The population moves to the assumed best candidate solution, and the position update mathematical formula is (1):

$$X_{j+1} = X_j - A\text{x}D \tag{1}$$

Where: $D = |C \text{ x } X_j{*} - X_j|$; $A = 2\text{a x r -a}$; $C = 2r$;*A* and *C* are coefficient vectors; *X** is the best spatial position of the current whale individual; *X* is the current spatial position of the whale group; *j* is the current iteration number, *a* is a linear decreasing constant from 2 to 0, expression Where is the maximum number of iterations of *M*; *r* is a random vector of [0, 1].

Bubble net attack: Using the range of variation of a, narrowing the range of the optimal solution, and then finding the optimal solution by spiral swimming, the mathematical expression is (2):

$$X_{j+1} = D' \, e^{bl} \cos(2\pi l) + X_j{*} \tag{2}$$

Where: $D' = |X_j{*} - X_j|$, D' is the distance from the current best position of the *i*-headed whale to the optimal solution, and *b* is the defined spiral shape constant set to 1, *l* which is a [-1, 1] random number.

The random number with *P* is [0, 1] is determined when $P < 0.5$ is a wrap-around predation, and the other is a spiral narrowing range;

Search Predation: When *A* does not belong to [-1,1], the whale group randomly selects the optimal solution in the global, the mathematical expression is as follows (3):

$$X = X_{rand} - A\text{x}D \tag{3}$$

Where: $D = |C \text{ x } X_{rand,j} - X|$; X_{rand} is an individual of a random whale;

In this paper, the electricity consumption Y, which consumes electricity, is the least objective function, ie, the following formula (4):

$$\text{Y=min } (\sum C\text{e}P\text{e}\Delta\text{t} + \sum C\text{w}P\text{w}\Delta\text{t}) \tag{4}$$

Among them: *C*e and *C*w are grid power price and PV price respectively; *Pe* and *Pw* are the grid power used and the photovoltaic power used.

The specific application whale optimization algorithm is: Initialize the whale algorithm parameters: the predicted total power consumption *P*t, the real-time electricity price data *C*ei and *C*wi will be collected, and the electricity consumption time is taken as unit time. The photovoltaic power generated continuously during the time period after the charging user makes an appointment is taken as the initial optimal whale position in the space as the candidate optimal solution set of the algorithm in the current time period, and the number of optimal groups is set to 3, and the number of iterations is set to 30 times. When the processor calculates the current optimal solution X^*, saves the current optimal position; determines whether the current iteration number j is less than or equal to the maximum number of iterations *M,* and if not, ends the calculation; if yes, updates *a, A*, *C,* and *p*.

When p is less than 0.5: When A<1, the current optimal position is updated with (1), otherwise the optimal position is updated with (3). When p is greater than or equal to 0.5: update the optimal position using (2), calculate the optimal solution using equation (4), and find the optimal position X^*, then, judged whether the algorithm stop condition is satisfied. If it is not satisfied, it is determined whether the current iteration number j is less than or equal to the maximum number of iterations M, and the iterative update is continued, and if yes, (3) is performed.

From the above steps, the optimal solution is output, that is, the minimum cost value and the current optimal position of the whale, that is, the photovoltaic power used. The control system uses the different commands to control the turn-on and turn-off of different combinations of the two-way thyristors according to the distributed photovoltaic power and grid power consumption obtained by the algorithm.

Conclusion

The photovoltaic-grid complementary electric charging system based on the whale optimization algorithm proposed in this paper uses the optimal solution of photovoltaic electricity consumption obtained by the whale optimization algorithm called in real time as the planning amount. The time window for calculating the dynamic parameters of the user charging behavior is optimized, so that the obtained charging law satisfies the loss as little as possible. The photovoltaic power generation, the real-time electricity price of the grid, the real-time electricity price of the photovoltaic, and the power loss are used as the control instruction reference quantity to meet the economical optimal and minimum loss control, which can effectively optimize the use of photovoltaic energy and traditional electric energy. It can realize effective planning of electric energy and photovoltaic energy, and turn traditional charging pile into photovoltaic-grid complementary power supply, which can accurately plan energy utilization and reduce the use cost. The algorithm has high precision and fast solution speed, and can provide accurate information for subsequent coordinated control, realizing the possibility of real-time control. The control system can effectively control the energy according to the instructions of the processor.

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