Research on Optimal Design of Microgrid Including Electric Vehicles

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Abstract: In view of the lack of consideration of electric vehicles in the design stage of microgrid, the use of traditional optimization algorithm in optimization design method, and only considering economic factors in optimization design index, this paper focuses on the mathematical model of electric vehicles, considering pollutants emission and other factors, and establishes a mathematical model of distributed energy. At the same time, the optimization design model of the microgrid and the constraints of the optimization problem were established, and the sparrow search algorithm with better comprehensive performance was used for reference. Finally, the optimization design and operation results of the microgrid were obtained. The simulation results proved the scientific and feasibility of the microgrid with electric vehicles under the new algorithm.

Keywords: Power system, Microgrid, New energy, Sparrow optimization algorithm, Optimization design.

1. Introduction

1.1. Mathematical Models of Climatic Factors

Both wind power generation and photovoltaic power generation are affected by weather factors. It is mentioned in literature [7] that wind speed changes constantly in a particular location, which depends on the local land terrain, weather system and ground height. Therefore, it is necessary to capture the change of wind speed in the model to predict power generation [8]. The Weibull probability density function can describe the change of wind speed. The Weibull probability function of wind speed (V) can be expressed as:

\[ f(V, k, c) = \left( \frac{k}{c} \right) \left( \frac{V}{c} \right)^{k-1} \exp \left[ -\left( \frac{V}{c} \right)^k \right] \] (1)

As for the probability of temperature distribution data, the probability function described in literature [9] allows modeling of temperature behavior in system design. Distribution parameters are calculated with temperature data, and the formula is as follows:

\[ f(T_a, h, n) = \left( \frac{1}{nh} \right) \sum_{i=1}^{n} K \left( \frac{T_a - T_{a,i}}{h} \right) \] (2)

Compare and select the calculation formula of light radiation conforming to probability density function:

\[ f(r) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha) \Gamma(\beta)} \left( \frac{r}{r_{\text{max}}} \right)^{\alpha-1} \left( 1 - \frac{r}{r_{\text{max}}} \right)^{\beta-1} \] (3)

1.2. Distributed Energy Mathematical Model

According to the current research on photovoltaic power generation, the output power of photovoltaic power generation can be expressed as:

\[ P_{\text{pv}}(t) = f_{\text{pv}} \frac{G(t)}{G_0} \left[ P_{\text{m}}^0 + \mu_{\text{pv}} (T(t) - T_{\text{m},0}) \right] \] (4)

Many wind power models such as WPMS, WPPT, Prediktor, ARMINES, Prevenio and WPFS Ver1.0 have been developed internationally. Among them, the commonly used mathematical model of wind power generation is:

\[ P_w(t) = \begin{cases} \frac{P_{\text{w}}} {v^2 - v_c^2}; & v_c \leq v \leq v_g \\ \frac{P_{\text{w}}} {v^2 - v_c^2}; & v_g \leq v \leq v_f \\ 0; & v < v_c \text{ or } v > v_f \end{cases} \] (5)

The output power of the diesel generator (PG) is:

\[ P_{\text{dg}}(t) = \eta_{\text{dg}} P_{\text{dg}}(t) \] (6)

The energy storage formula established in this study for pumped storage system is as follows:

\[ E_{\text{bd}}(t+1) = E_{\text{bd}}(t) \left( 1 - \gamma_{\text{bd}} \right) + 3600 \left[ q_{\text{in}}(t) - q_{\text{out}}(t) \right] \] (7)

The energy in the battery described in reference [10] accords with the expression in Formula (8), and takes into account that the charging and discharging powers are expressed by different variables Pbc and Pbd, both of which are positive.

\[ E_{\text{b}}(t+1) = E_{\text{b}}(t) \left( 1 - \gamma_{\text{b}} \right) + \left[ \eta_{\text{b}} P_{\text{b}}(t) - \frac{1}{\eta_{\text{b}}} P_{\text{bd}}(t) \right] \] (8)
1.3. Mathematical Model of Electric Vehicle System

The types of electric vehicles are mainly divided into two types: the first type of electric vehicles, can only be used as charging load, can not provide energy output system. The second type of electric vehicle can be used as charging load or energy source to provide energy to the system. The second type of electric vehicle obeys the probability density function shown in Formula (9).

\[
f(d) = \frac{1}{d\sigma\sqrt{2\pi}} \exp\left[-\frac{(\ln d - \mu)^2}{2\sigma^2}\right]
\]  

(9)

Therefore, through statistical random sampling of the cumulative probability of the above normal distribution and lognormal distribution, PEV's departure time, arrival time and daily driving distance can be obtained.

2. Optimization Design Model of Microgrid Including Electric Vehicles

2.1. Modeling of Microgrid Optimization Design Model Including Electric Vehicles

In order to clarify the optimization problem, the battery needs to consider the different charge and discharge power, the power and pumping power generated by the turbine in the pumped storage system, the different types of charge and discharge power of electric vehicles, etc. Therefore, the degree of freedom of the design of the optimization variable can be obtained as follows: Number of photovoltaic panels (Npv), number of wind turbines (Nwt), Number of batteries (Nb), volume of water tank of pumped storage system (V), power transmitted by diesel generator set per hour (Pbd(T)), battery charging power per hour (Pbc(T)), battery discharge power per hour (Pbd(T)), The power of water pumped per hour (Pbat)), the power of water wheel delivered per hour (Pwt(T)), the power generated by the turbine in the pumped storage system (V), power transmitted by diesel generator set per hour (Pbd(T)), battery charging power per hour (Pbc(T)), battery discharge power per hour (Pbd(T)), and unsupplied power demand per hour (Pns(t)).

The optimization variable can be expressed as a one-dimensional matrix:

\[
x = \begin{bmatrix} N_{pv} & N_{wt} & N_{b} & V & P_{bat}(t) & P_{bc}(t) & P_{bd}(t) & P_{ns}(t) \end{bmatrix}
\]  

(10)

The objective function of this study is a multi-objective optimization function, which is essentially a multi-objective optimization problem. The objective function mainly includes the annual cost CT of the system and the total carbon dioxide emission ET of the system.

Combined with the research focus of this paper, the total annual cost of the system can be described as follows:

\[
C_T = C_{cp} + C_{mw} + C_G
\]  

(11)

Total system carbon dioxide emissions, total system emissions generated during component construction and diesel generator operation, ET is calculated by:

\[
E_T = \sum E_{G,0} \cdot \left( \frac{1}{2} \cdot \max(P_{bc}(t)) + \max(P_{bd}(t)) \right) + \sum_{j=1}^{J} \left( \sum_{i=1}^{I} E_{C,G,0} \right)
\]  

(12)

To solve this multi-objective optimization problem, a weighted summation method will be used, in which a weight factor is assigned to each objective, as shown in Formula (20) (a weight factor is assigned to CT and a weight factor wEET to total emissions).

\[
f = \min \left( C_T + w_E E_T \right)
\]  

(13)

2.2. Optimize Design Model Constraints

Battery pack, type 2 EV battery and pumped storage system must be kept within the permitted operating range. The specific requirement constraint formula is as follows:

\[
N_{b}E^w_{b} \leq E_{b}(t) \leq N_{b}E^M_{b}
\]  

(14)

\[
0 \leq E_{ns}(t) \leq V
\]  

(15)

\[
3E^w_{v} \leq E_{v}(t) \leq 3E^M_{v}
\]  

(16)

The daily discharge of type 2 electric vehicle must be greater than or equal to 80% of the energy used in daily travel during the running time. The specific demand constraint formula is as follows:

\[
M_{v}P_{v2d} \geq 0.8 \left( \frac{3}{h_v} \right)
\]  

(17)

2.3. Research on Sparrow Optimization Algorithm

The economic dispatching of microgrid is a nonlinear, multi-model, multi-objective complex system optimization problem. At the same time, based on the advanced in the field of artificial intelligence all sorts of modern intelligent algorithm is also gradually be applied to the actual power system engineering design, the early main using functional analysis, fuzzy system, genetic algorithm (ga) optimization method, but with the development of computer technology, the traditional intelligent optimization algorithm in convergence speed, precision, etc have been unable to meet the increasingly complex problems. In recent years, new intelligent algorithms such as new swarm intelligence optimization algorithm and new intelligent optimization algorithm have been proposed gradually. Through detailed comparative analysis, it is found that the performance of the latest sparrow search algorithm is outstanding, and it has good results in solving accuracy, convergence speed and execution time. Sparrow Search Algorithm (SSA) is an effective optimization technology, which simulates the group intelligence foraging and anti-predation behavior of sparrows. Compared with many other small birds, sparrows have strong intelligence and strong memory, so SSA can be rapidly promoted and applied. The techniques involved are used to solve global optimization problems because of their simplicity, flexibility, and efficiency.

3. An Example of Optimal Design of Microgrid with Electric Vehicle

3.1. Optimization Design Results of Microgrid Including Electric Vehicles

Containing micro grid optimization design of electric cars through the sparrow search algorithm to calculate the optimal design results are shown in table 1, as can be seen from the table, the amount of electric cars in 50 vehicles, including type 1 as charging electric cars only 20, type 2 can be two-way transmission of the electric car 30 energy, in order to avoid the randomness of wind power generation, There are only 6 wind turbines and 823 photovoltaic panels. The total annual cost of the optimized system includes the emission cost.
battery discharge power gradually rise, when the energy storage battery power down to a certain level, just as the evening peak, began to increase the output power of diesel generators, storage battery output power decreases, energy storage batteries store energy also gradually reduced. At this time, the power demand of the system is mainly diesel power generation.

The electric power demand, pumped storage charge and discharge and water can run energy state, can be seen from the diagram, and the energy storage battery energy storage and put to work idea is consistent, in new energy output is large, by a gradual increase in pump pumping pumped storage power, at the peak, can begin to put through the turbine, So that the whole system can effectively use new energy to generate electricity, and at the same time meet the work of the system peak regulation operation.

4. Conclusion

In this study, an optimization design method of microgrid containing electric vehicles based on sparrow search intelligent algorithm is proposed, and the mathematical model of distributed energy of microgrid and the mathematical model of two kinds of electric vehicles are established, and the optimization model is further established and the constraint conditions are clarified. At the same time, the algorithm optimization of the microgrid and programming with MATLAB software verify the scientific and feasibility of the proposed method. This study initially solves the problems of electric vehicle integration and climate data considered in the design stage, and uses the new intelligent optimization algorithm to avoid lighter and wind losses, reflecting the due economic value. At the same time, the emission of CO2, SO2, NO and NO2 of the unit is the lowest, so as to achieve the effect of energy saving and economic improvement.

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