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Research on differentiated scheduling method of electric vehicle considering random probability

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Abstract. On the basis of the charging load of a single electric vehicle, in order to reduce the variance of the equivalent load curve and alleviate the peak plus peak caused by electric vehicles, a local electric vehicle charging cooperative scheduling model with the distribution network node as the optimization unit is set up. The model is composed of node agent and electric vehicle agent. The electric vehicle agent is based on the node load obtained. Rate information, combining with its own state, using random probability charging algorithm to make the decision to start charging or stop charging, and use IEEE-33 node system as an example to use MATLAB software for the designed electricity. The algorithm is verified by dynamic vehicle charging cooperative scheduling strategy. The results show that the proposed algorithm can effectively load the load curve and reduce the variance of load curve.

Keywords: Electric vehicle; collective motion; ordered charging; synegistic dispatch; random probability charging algorithm.

1. Introduction

A large scale electric vehicle access to the power grid, its disordered charging will lead to the peak of the load curve peak in the distribution network, threaten the safe operation of the power system, and reduce the economy of the system operation [1]. At the same time, distributed generation and electric vehicles are widely connected to the power grid, which makes the center of gravity of the power system structure shift to the "load" side, and the amount of information to be collected increases exponentially. Under the traditional "many to one" information transmission mechanism, there are bottlenecks in the information transmission channel and computer processing capacity, making the traditional centralized dispatching method no longer feasible [2-4]. It is necessary to study the cooperative scheduling method suitable for the wide access of distributed resources to the power grid.

Based on the cluster motion theory and aiming at reducing the variance of the equivalent load curve, this paper studies the charging collaborative scheduling strategy of electric vehicles. Each electric vehicle is regarded as an agent with independent decision-making [5]. According to the information of other power generation and consumption objects in a certain neighborhood, the electric vehicle adopts the random probability charging algorithm to decide whether to charge or not. The feasibility and effectiveness of the designed cooperative scheduling algorithm are verified by MATLAB simulation software.

2. EV charging collaborative scheduling process

Assuming that the electric vehicle is connected to the power grid at time t, the required power and the time required to complete charging are calculated according to the driving demand of the electric vehicle, and finally the latest charging time T_{last} of the electric vehicle is obtained. If $t = T_{last}$, no matter the node load rate is high or low, the electric vehicle starts charging immediately, and then it is no longer controlled until the charging is completed. If $t < T_{last}$, it indicates that the electric vehicle has sufficient charging time and can be scheduled. Enter the following scheduling process.

1) Charging process

The electric vehicle receives the load rate information of the access node, and when the node load rate $r < \lambda_1$, the electric vehicle immediately charges; When $\lambda_1 < r < \lambda_2$, the electric vehicle charges immediately with probability p_1 and requests charging again with probability $1-p_1$ delay time t_d ;When $r > \lambda_2$, the electric vehicle delay time requests charging again.

2) Stop the charging process

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The threshold λ_2 indicates that the node is close to full load. When $r > \lambda_2$, if the load continues to increase, the node is at risk of overload. Therefore, in addition to stopping the charging of electric vehicles, it is also necessary to stop the charging behavior of some charging electric vehicles. The process of stopping charging is, the electric vehicle being charged stops charging with the probability of p_2, and tries to charge again after waiting time t_d, and continues charging with the probability of $1-p_1$.

3. Design of random probability charging algorithm

The principle of charging probability threshold generation algorithm is: firstly, ensure that the electric vehicle power meets the owner's requirements before the electric vehicle owner leaves the charging pile; Secondly, we should ensure the economy of power grid operation, improve power grid efficiency, and ensure that the real-time power of all nodes cannot exceed the maximum power supply capacity of the node. Therefore, the goal is to minimize the variance of load curve; Finally, the algorithm should not be based on the accurate prediction of future load information, but only need to obtain real-time load information.

In order to meet the algorithm objectives, first, when the running time t reaches the latest charging time of the electric vehicle, the electric vehicle does not accept any control and starts charging until the charging is completed. Secondly, when the node load rate is greater than the threshold, the schedulable electric vehicle charging behavior connected to the power grid is limited; when the node load rate is greater than the threshold, the stop charging mechanism will start and stop the charging behavior of some charging electric vehicles, so as to ensure that the node load is at a safe and stable level. Therefore, when the electric vehicle is connected to the power grid, the intelligent experience of the electric vehicle will be based on the nodes received at the previous time Load rate information to make a decision to charge or stop charging.

3.1 Start charging function design

According to the requirements of random charging algorithm, when the node load rate r slightly exceeds the threshold λ_1, the starting charging probability $p_1(r)$ should be close to 1, and when it approaches the threshold λ_2, it should quickly drop to the minimum value close to 0.At the same time, the waiting time of electric vehicles should also be considered to ensure the fairness of charging. Therefore, it is designed as an exponential function about r, as shown in formula (1). As shown in the figure 1, with the increase of, the concave of the function curve becomes stronger and stronger.

$$p_1(r) = \begin{cases} e^{-\alpha(r-\lambda_1)+\beta t_w/t_m}, & t < T_{last} \\ 1, & t = T_{last} \end{cases} \tag{1}$$

$$t_w = t_m - t_c$$

$$t_m = t - T_a$$

Where, t_w represents the accumulated time of the electric vehicle without charging, t_m represents the accumulated time of the electric vehicle access time, t_c represents the accumulated charging time after the electric vehicle connected to the power grid, t represents the current operation time, and t_w / t_m represents the waiting factor after the electric vehicle connected to the power grid β; α indicates the rapidity parameter that drops to 0 when the node load rate is greater than λ_1.

When r is greater than λ_1, p_1 decreases exponentially with the increase of r, so there are only a few electric vehicles to charge, so as to ensure that the node load rate will not increase further. When $t < T_{last}$, in order to ensure the formula $p_1(\lambda_1)=1, p_1(\lambda_2)=\varepsilon$ (here represents the positive decimal), α is determined by formula (2).

$$\alpha = \frac{\ln \varepsilon}{\lambda_1 - \lambda_2} \tag{2}$$

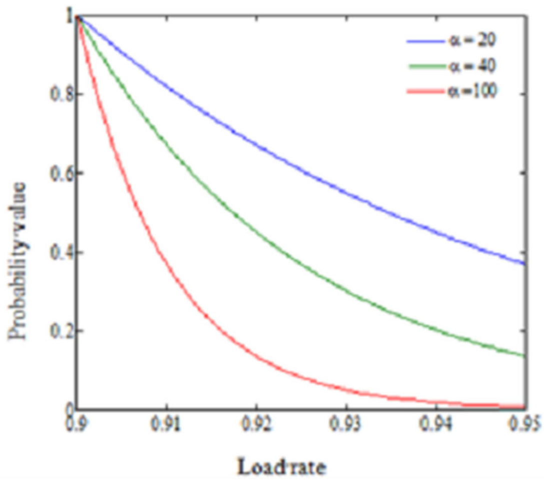

Fig. 1 Different α corresponding curves

According to the random probability charging rule, the probability of electric vehicle charging request being allowed is p_1 and the probability of being rejected is $1-p_1$. When the electric vehicle charging request is rejected, the electric vehicle will send the charging request again after a delay time t_d. The determination rule of delay time is: when $T_{last} - t > t_n$, the delay time is randomly determined from the set $\left[0,t_n\right]$, and when $T_{last}-t\le t_n$, the delay time is determined as $T_{last}-t$.

3.2 Stop charging function design

When the node load rate r exceeds the threshold λ_2, the stop charging mechanism starts. p_2 indicates the probability that the electric vehicle stops charging. Obviously, when r is slightly exceeded λ_2, the value p_2 should be small to avoid too many charging electric vehicles stopping charging and affecting the owner's charging experience; When r is close to 1, it shall be increased rapidly to prevent node overload. Therefore, we design the stop charging probability p_2 as an exponential function of r, as shown in formula (3).

$$p_2(r)=\begin{cases} e^{\gamma(r-1)}, & t<T_{last} \\ 0, & t=T_{last} \end{cases} \qquad (3)$$

$$\gamma=\frac{\ln\varepsilon}{\lambda_2-1}$$

Figure 2 shows the function curves corresponding to different γ values in the case of $\lambda_2=0.9$. It can be seen that the concave characteristic of the function curve gradually increases with the increase of γ. When $\gamma\ge 30$, it is slightly exceeded λ_2, the probability of stopping charging is small, which closed to 0, and when r is close to 1, the probability of stopping charging increases rapidly, which close to 1. Therefore, the design function can meet the requirements of demand side response.

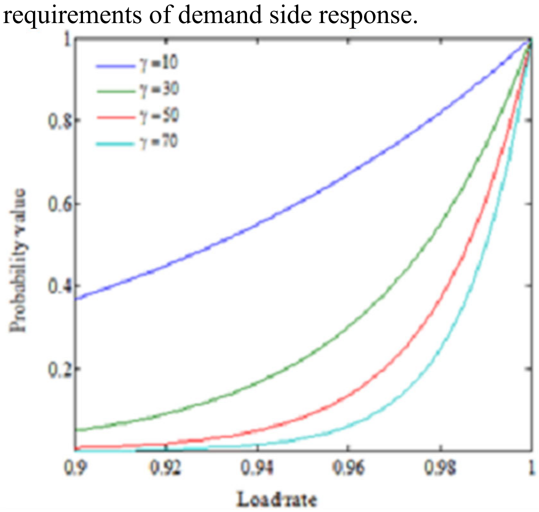

Fig. 2 Function curves under different node load rates

3.3 Example analysis

In this paper, IEEE-33 node example system] is used for simulation analysis. Its wiring is shown in Figure3. Node 1 is the system balance node, the system power reference value is s = 100MVA, the total basic active load of the system is 3.715MW, and the active capacity of distribution transformer is 6500kW. The 24-hour basic load curve of the system is shown in Figure 4.

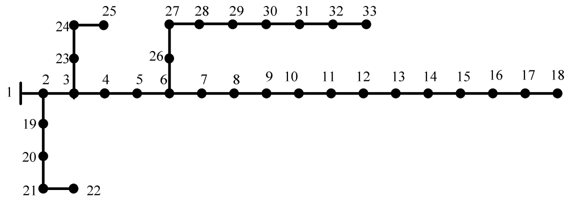

Fig. 3 IEEE-33 node system wiring diagram

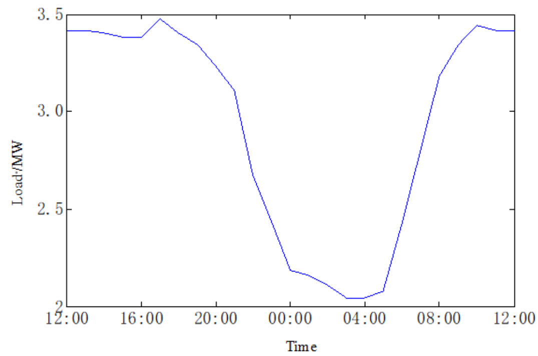

Fig. 4 24-hour basic load curve

The day is divided into 2400 time periods. 12:00 noon is the zero operation time, and 12:00 the next day is the 2400 operation time. The maximum allowable power of each node takes the node active power reference value, for example, the maximum allowable power of node 25. Battery capacity of electric vehicle. The charging mode of electric vehicle is slow charging mode. Refer to the literature for parameters such as charging power, driving habits and daily driving mileage of electric vehicles. Electric vehicles are evenly distributed and connected to each node.

Monte Carlo simulation is conducted for disorderly charging and collaborative dispatching charging of 1000 electric vehicles and 1500 electric vehicles connected to the system. Each case is simulated 100 times, and the average value is taken as the simulation result.

Tab. 1 Parameter values of cooperative scheduling algorithm under different vehicle access conditions

Parameter	λ_1	λ_2	ρ	ε	α	β	γ
N=1000	0.854	0.855	0.5	e^{-1}	1000	0.307	6.90
N=1500	0.938	0.940	0.5	e^{-1}	500	0.307	16.67

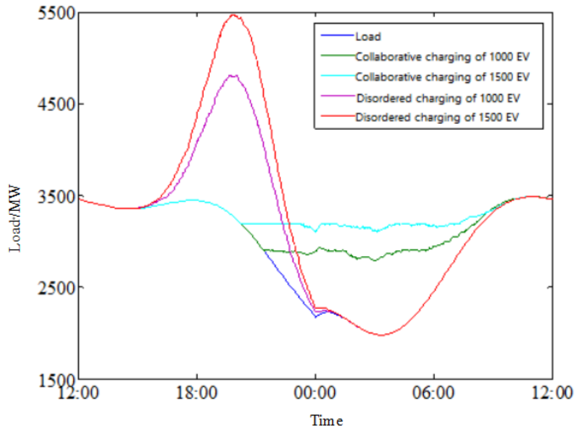

Fig. 5 Total load curve of different number of EV under disordered charging and collaborative dispatching charging modes

4. Conclusion

Aiming at minimizing the variance of load curve, a local cooperative dispatching model for electric vehicle charging is established in this paper. As an independent individual, according to the received node load rate information, combined with its own state information, aiming at the minimum variance of the load curve, the electric vehicle spontaneously makes the decision of charging or stopping charging by using the stochastic probabilistic control algorithm. Through this distributed local decision algorithm, the global expected peak cutting and valley filling function can be realized as much as possible.

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