

Research on Electric Vehicle Entry Control Strategy Based on Different Scenarios

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Abstract. Environmental pollution is becoming more and more serious. Traditional vehicle exhaust is one of the most important sources of pollution. Compared with traditional cars, electric vehicles have the characteristics of energy saving, emission reduction and pollution free. Large scale electric vehicles will impact the original distribution system to varying degrees. When the valley load is low, the electric vehicle can be charged as a load and connected to the system to recharge. At peak load, electric vehicle can be used as energy storage element to provide power for grid. The orderly access of electric vehicles to the power grid is much less than that of the disorderly access to the grid. For a specific area, the coordination of electric vehicle group with wind power, photo-voltaic power generation or micro grid can provide guarantee for the stability of power system. This paper makes a comparison and analysis of the control strategy of electric vehicles in different scenes, and puts forward the shortcomings in the study of the control strategy, which provides a reference for further research.

1. Introduction

Global warming has become one of the most important problems facing mankind. Reducing carbon dioxide emissions is the fundamental way to solve this problem. In the national "12th Five-Year plan" plan, the Chinese government clearly pointed out that the target of reducing carbon dioxide emissions per unit of GDP to 17%. Effect of EPRI brings to the integration of electric vehicles in 2012 conducted a series of studies.

Carbon dioxide is used as the target of energy saving and emission reduction in planning, and the new concept of low carbon environmental protection is introduced in [1], and the objective function is to maximize the economic income of low carbon benefit. Based on the planning and measured data of North China and northwest power grid, the dispatch of electric vehicles is used to smooth the fluctuation of load and to absorb the possibility of excessive night wind power [2]. Literature [3] is based on the two phase charge model of lithium battery, which is based on the initial charge state (random distribution) and the time of arriving at the charging station (random distribution). The aggregation model of the two stage electric vehicle charging station is put forward, and the characteristics of the Poisson distribution characteristics are simulated. In document [4], an electric vehicle group scheduling strategy is proposed, which selects the end time of travel, the required charge time, the starting trip time and the maximum



charge delay length as the discriminant for the group of electric vehicles. Document [5] proposes a micro-grid based operation mode of electric vehicle switching station, and establishes a charging and discharging model of the power station. The development of distributed generation and electric vehicle has developed a lot. [6], electric vehicle can be regarded as a special energy storage element. Based on the idea of layered zoning scheduling for electric vehicles, a [7] based charging and discharging scheduling model of electric vehicles can be built based on bi level optimization. Document [8] is based on the characteristics of the random distribution of electric vehicle charging, and applies the fuzzy K-means algorithm to design the specific electric vehicle emergency power supply plan.

At present, there are mainly three ways to recharge electric vehicles: fast charging, slow charging and battery replacement [9]. The popularity, type, charging time, charging mode and different charging characteristics of electric vehicles will change the impact of electric vehicles on the power grid [10]. Usually, a large number of electric vehicles choose to charge at night, which can improve the load curve of electric power and improve the economic benefits of power grid.

Document [11] put forward a mathematical statistics modeling method to establish the charging and discharging power model and time-varying load model of electric vehicle under different control modes. Taking the 10kV line of a city as the research object [12], the influence of electric vehicle charging on the distribution network is deeply analyzed from three aspects of load, power grid loss and voltage. Document [13] proposed a prediction method of electric vehicle charging load based on the characteristics of electric vehicle driving and parking and considering the time and space distribution. Document [14] introduces the concept of hierarchical partition scheduling, and establishes a two level intelligent charging and discharging model of electric vehicle based on bi level programming. Document [15] the formulation of charging price for electric vehicle is closely related to the relationship between operators and consumers. How to make reasonable electricity price affects the development of the whole electric vehicle industry. The main factors of charging demand and factors affecting charging demand are analyzed in literature [16], and an orderly charging scheme for charging load configuration and charging demand is proposed. According to document [17], in order to solve the problem of orderly scheduling of electric vehicles, a real-time electricity price model based on electricity price leverage is proposed to regulate the fast charging load of electric vehicles.

2. Charging facilities planning for electric vehicles

For the power network load, the charging facility is the interface between the electric vehicle charging and the power grid, and the planning of the charging facilities has a great influence on the charging load of the electric vehicle. The access mode of the charging station is influenced by the reliability of the power supply, the scale of the construction and the cost of the construction. The layout of electric vehicle charging station focuses on two factors: demand and possibility. For demand, there are mainly traffic volume and service radius. The impact of electric vehicle charging on the power grid is greatly influenced by the commercial development mode of electric vehicles, and there is great uncertainty. From the perspective of load balance, the characteristics of electric vehicle use and charging time have the function of peak shaving and valley filling.

From the perspective of the future development of electric vehicles, the distribution and capacity allocation of electric vehicle charging facilities is mainly considered in the short term. In the long run, with the development of charging technology and metro-logy technology, large scale distributed household charging to the power grid must consider important aspects. Electric vehicles supply infrastructure to power grid through electric energy. Various types of chargers and charging piles are the power supply terminals for electric network. The power grid provides two main services for electric vehicles: Vehicle oriented and battery oriented, and the components of the two charging are the same. Complete the vehicle or battery charging at a specific location and effective time.

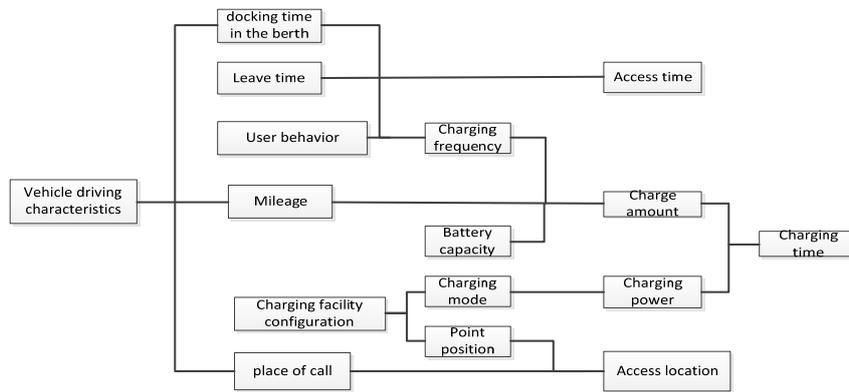


Figure 1. Electric vehicle charging demand and influencing factors

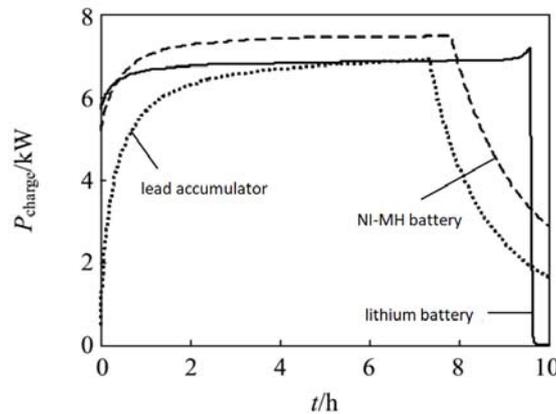


Figure 2. The charge power curve of three kinds of batteries

3. Application of electric vehicle group

As a walking tool of clean energy, electric vehicle has the characteristics of high efficiency, environmental protection and so on. Electric vehicle charging and discharging has obvious spatio-temporal characteristics, and disorder will bring serious influence to the power grid. The reasonable control of electric vehicle charging and discharging can avoid the fluctuation brought to the grid load, reduce the load peak and valley difference and improve the utilization ratio of electric network.

(1) Mathematical model of travel law of electric vehicle

In 2009, the related data in the US family car survey report can describe the [18] characteristics of electric vehicles. The normal distribution is used to fit the trip end time T_{end} and the start time T_{start} . The logarithmic normal distribution is used to fit the daily mileage D . The probability density function $f_e(x)$, $f_s(x)$, $f_d(x)$ and the long charge time t_{ev} are calculated by the running mileage data of the day.

$$f_e(x) = \begin{cases} \frac{1}{\sigma_e \sqrt{2\pi}} \exp\left(-\frac{(x+24-u_e)^2}{2\sigma_e^2}\right); 0 < x \leq u_e - 12 \\ \frac{1}{\sigma_e \sqrt{2\pi}} \exp\left(-\frac{(x-u_e)^2}{2\sigma_e^2}\right); u_e - 12 < x \leq 24 \end{cases} \quad (1)$$

In the formula: $u_e = 17.6$; $\sigma_e = 3.4$

$$f_s(x) = \begin{cases} \frac{1}{\sigma_s \sqrt{2\pi}} \exp\left(-\frac{(x-u_s)^2}{2\sigma_s^2}\right); 0 < x \leq u_s + 12 \\ \frac{1}{\sigma_s \sqrt{2\pi}} \exp\left(-\frac{(x-24-u_s)^2}{2\sigma_s^2}\right); u_s + 12 < x \leq 24 \end{cases} \quad (2)$$

In the formula: $\mu_s=9.24$; $\sigma_s=3.16$

$$f_d(x) = \frac{1}{x\sigma_d\sqrt{2\pi}} \exp\left(-\frac{(\ln x - \mu_s)^2}{2\sigma_d^2}\right) \tag{3}$$

In the formula: $\mu_d=3.2$; $\sigma_s=0.88$

(2) Prediction method of electric vehicle charging load

Document [13] starts from the spatial and temporal distribution characteristics of electric vehicle's daily mileage and daily parking demand, and analyzes the spatio-temporal model of parking demand. The development of the electric vehicle industry is mainly influenced by three factors, including the price, the mileage and the charging facilities.

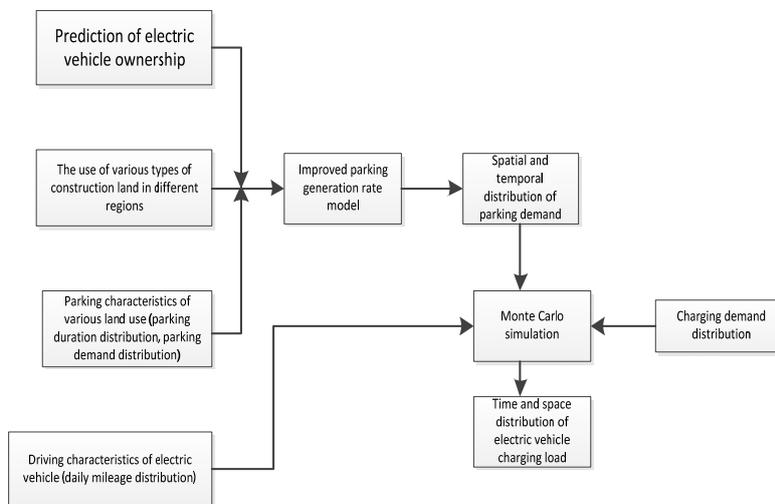


Figure 3. Charging load prediction of electric vehicle considering time and space distribution

(3) Distributed energy storage model of electric vehicle

In a suspended state under the electric vehicle for the electric grid can be used as a distributed energy storage unit. [19] Electric vehicle can exchange information with distributed energy storage control center, and achieve dual energy exchange with grid. Distributed energy storage of electric vehicles needs decentralized control mode, which requires information platform built by smart grid.

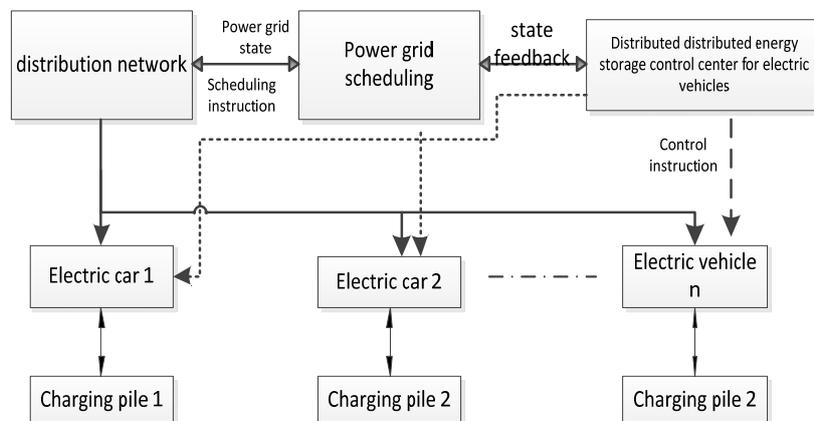


Figure 4. Distributed energy storage system for electric vehicles

4. Consideration of the control strategy of electric vehicle under different factors

4.1. Control strategies for carbon emissions

Document [1] takes the largest objective of low carbon efficiency in the planning period as the objective function, and determines the coordinated investment strategy of wind power generation, photo-voltaic power supply and electric vehicle charging station:

$$\max x_{LCP} = \frac{\sum_{t=1}^T (Q_{Cce,W,t} + Q_{Cce,S,t} + Q_{Cce,C,t})}{\sum_{t=1}^T (C_{Inv,W,t} + C_{Inv,S,t} + C_{Inv,C,t})} \quad (4)$$

In the formula: x_{LCP} is low carbon income, $Q_{Cce,W,t}$ is a wind power generation, $Q_{Cce,S,t}$ generates electricity for photovoltaic power. D is the quality of CO₂ reduction for electric vehicle charging stations. $C_{Inv,W,t}$ is an investment in wind power plant planning. $C_{Inv,S,t}$ shows the investment of the photo-voltaic power plant in the planning period. $C_{Inv,C,t}$ represents the investment of electric vehicle charging stations during the planning period. The period of investment is in a period of 5 years.

The goal is to maximize the benefit of low carbon economy, and establish a coordinated planning investment model for *PV*, wind power and electric vehicle charging stations. The low carbon benefit of the electric vehicle charging station has great relationship with the power structure distribution of the power generation side. By reducing the carbon emission factor of thermal power plants, we will invest in clean energy and increase the economic benefits of electric vehicle charging stations. The transfer from low carbon efficiency to economic benefit has been achieved.

Document [5] put forward that adding electric vehicle group to power station on the basis of original micro-grid can store electric energy into power battery pack. The electric vehicle group can be powered by changing the battery. When the electricity price is high, the electricity stored in some batteries is fed back to the power grid. The switching power station has the features of centralized charge discharge.

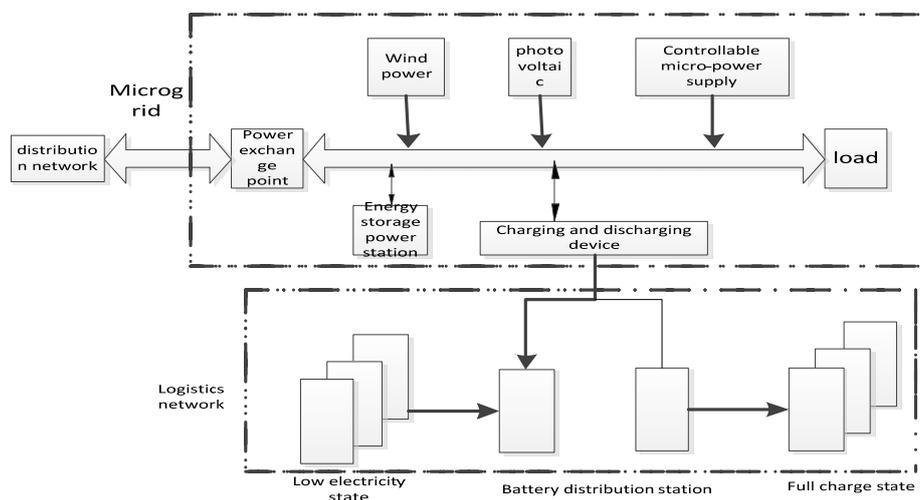


Figure 5. Operation mode of switching power station based on Micro-grid

4.2. Consideration of wind power control strategy

Literature [2] electric vehicles increase the peak load in the daytime under the free charging mode. When the electric vehicle is concentrated, the peak load of the power grid will increase. The demand for peak shaving capacity and the expansion of transmission and distribution equipment are increased. According to the results of relevant scheduling regulations and wind power prediction, we choose different M

values to schedule electric vehicles at corresponding time scales. The variance and minimum of the equivalent load in each time window are taken as the objective function:

$$\min \sum_{i=1}^{T-M+1} \sum_{t=i}^{i+M-1} (P_{lt} - P_{wt} + P_{cv,t} - P_{av,i})^2 \quad (5)$$

Formula: P_{lt} said t at the time of power load; P_{wt} represents the wind power that is connected to the t period. $P_{cv,t}$ indicate the charging power of electric vehicles in the t period. $P_{av,i}$ - the average value of the equivalent load of i time window.

Reasonable number of electric vehicle charging scheduling can be used to offset load drop or increase. With the increase of electric vehicle access scale, improve the load characteristics, wind power consumptive excess benefit increase. It can achieve the coordinated and complementary utilization of wind power and electric vehicle energy storage resources. The charge and discharge scheduling strategy proposed by document [4] is the objective function of minimizing the power fluctuation in the distribution network:

$$\tilde{F}_{obj} = \sqrt{\sum_{t=1}^{24} (P_{L,t} - P_{ev,t} - P_{pv,t} - \frac{\sum_{t=1}^{24} P_{L,t} + P_{ev,t} - P_{pv,t}}{24})^2} \quad (6)$$

In the formula: $P_{L,t}$ represents the load of the distribution network. $P_{ev,t}$ represents the active power interval of electric vehicles at t time. $P_{pv,t}$ represents the active power generated by photo-voltaic generation system at t time.

A group scheduling strategy based on four discriminant quantities, which is based on the trip end time, the start time of the trip, the long charge time and the maximum charge delay, is proposed, which is only based on the theoretical deduction. If the photo-voltaic power generation system is replaced by the wind power system, the discriminant quantity of the model needs a certain change, and it is related to the characteristics of the power station (PV and wind power generation) according to the specific area time and the setting of the discriminant.

4.3. Control strategy under real time electricity price

Document [17] transfers load from high price period to low price period. The relationship of demand change caused by the fluctuation of electricity price:

$$\begin{bmatrix} \Delta q_1 & \Delta q_2 & \dots & \Delta q_n \\ q_1 & q_2 & & q_n \end{bmatrix}^T = E \begin{bmatrix} \Delta p_1 & \Delta p_2 & \dots & \Delta p_n \\ p_1 & p_2 & & p_n \end{bmatrix}^T \quad (7)$$

According to the results of short-term load forecasting, real-time electricity price is set up to control user's choice time and achieve orderly charging, so as to achieve the purpose of peak shaving and valley filling.

The goal of real-time pricing is to guide users to adjust charging time and achieve peak load shifting. The peak valley difference is taken as the target function, and the load of electric vehicle charging load is optimized under the T_a - T_b time period, which makes the peak valley difference of the new load curve minimum:

$$\min (L_{\max} - L_{\min}) = \max_{\substack{j=1 \\ h \in [T_a, T_b] \\ i \in [h, T_b]}}^{n(h)} (L_i + \sum_{j=1}^{n(h)} P_j x_{ij}) - \min_{\substack{j=1 \\ h \in [T_a, T_b] \\ i \in [h, T_b]}}^{n(h)} (L_i + \sum_{j=1}^{n(h)} P_j x_{ij}) \quad (8)$$

In the formula: \mathbf{L}_{max} represents the maximum load; \mathbf{L}_{min} represents the minimum load; \mathbf{h} is the variable for the study of the time period. \mathbf{P}_j represents the charging power of the j electric vehicle, and \mathbf{x}_{ij} represents the decision variable.

In the V2G operation mode, electric vehicles can feed electricity to the power grid when the system needs. By developing reasonable real-time charging and discharging tariff, users are encouraged to participate in interactive scheduling actively.

4.4. Two layer scheduling control strategy

In literature [7] the upper level objective function contains two items, and the first one is the variance of the total load of the system. The second one is the deviation between the actual dispatching result of the lower level agents and the scheduling plan determined by the system dispatching organization. The objective function of the optimization is as follows:

$$\min F = \frac{1}{T-1} \sum_{t=1}^T (P_{d,t} + \sum_{k=1}^{N_0} x_{k,t} - \tilde{P}_d)^2 + \alpha \sum_{k=1}^{N_0} f_k(X_k, Y_k) \quad (9)$$

In the lower layer model, the agents have the minimum deviation between the actual load of the agent and the scheduling plan made by the dispatching organization through the control of the charge and discharge state of the electric vehicles in the near area.

For the k agent, its objective function can be expressed as:

$$\min_{Y_k} f_k(X_k, Y_k) = \sum_{t=1}^T \left(\sum_{m=1}^{n_k} P_{k,m,t} - x_{k,t} \right)^2 \quad (10)$$

In the literature [14], in the regional level, the electric vehicle operators take the maximum profit as the optimization goal. Without affecting the safety of distribution network, the relevant algorithm is applied to get the best area charge and discharge power of $P_{k,t}$ in different jurisdictions within 24 periods of a day.

$$\max \left\{ \sum_{t=1}^T \left[\sum_{k=1}^X C_{k,t}^S P_{k,t} - C_t^P \sum_{k=1}^X (P_{k,t} - \beta_k P_{w,t}) - C^W P_{w,t} - \sum_{k=1}^X C_{k,t}^r P_{k,t} \right] \Delta t - \partial |f(\Delta)| \right\} \quad (11)$$

In the formula: $\mathbf{P}_{k,t}$ is the k charging jurisdiction area. The total charge and discharge power in t period belongs to the control variable of the regional level. $\mathbf{C}_{k,t}^s$ indicates the two-way sales price of k users in the t period. \mathbf{C}_t^p represents the two-way purchase and sale price between the operators and the power grid. \mathbf{C}^w calculates the unit cost of wind power for operators. $\mathbf{C}_{k,t}^r$ represents the operation and maintenance cost of the k charging area in t period. $\mathbf{P}_{w,t}$ represents the force of the wind farm during the t period.

In the users' layer:

The charging and discharging operators of electric vehicles are optimized according to the actual results of the dispatching center and the minimum absolute value of the reference data deviation of the regional layer, and take into account the users' charge and discharge requirements. The charge and discharge control strategy of each electric vehicle is obtained by sequential selection method. The objective function of users' layer:

$$\Delta P = \min \sum_{t=1}^T \sum_{k=1}^X \left[\sum_{m=1}^N P_{k,m,t} - P_{k,t} - \text{Sat}_{k,t} \right] \quad (12)$$

Among them: $\mathbf{P}_{k,m,t}$ is the charging power of m electric vehicle at t hour in area k . $\mathbf{Sat}_{k,t}$ is the related element in the user satisfaction matrix.

In literature [7] in the upper model, through the different scheduling plans for the various electric vehicle agents, the system can minimize the variance of the total load level in the time interval to reach the goal of cutting the peak and filling the valley. In the literature [14] level model, we optimize the total charge and discharge power of each jurisdiction in each period, and maximize the operator's profit. It is reasonable to avoid the adverse effects of electric vehicle charging and discharging on the power grid. In the lower layer model of literature [7], the electric vehicle agent can manage the charge and discharge time of the electric vehicle under the jurisdiction, so that the lower layer and the upper level plan are consistent. In the literature [14], the specific charge and discharge strategy of electric vehicles in each jurisdiction is optimized in the upper and lower layer model, so that the scheduling strategy of the lower layer is consistent with the maximum total charge and discharge power of the upper layer.

5. Summary

If a large number of electric vehicles are widely applied, if they are allowed to disorder, they will threaten the safety and economic operation of the power system. The energy storage characteristics of automotive batteries help to improve the safety and economy of the system.

The layered zoning control strategy is to realize the organic unification of the charging station operators, the Power Grid Corp and the electric vehicle users through the interaction of the charge and discharge information between the regional layer and the user layer. The profit is maximized on the electric vehicle operator side; the power grid side ensures the security and stability of the urban distribution network system and improves the power quality; the user side leads the charge and discharge behavior to improve the user's satisfaction. Reasonable consideration of user satisfaction, through the data interaction between the upper and lower levels, can achieve the three win of power grid, operators and users. If a large number of electric vehicles are connected to the power grid, if they are not optimized and controlled, the safety and stability of the existing power grid will be seriously affected. The most important problem for operators to consider is to maximize profits, which is also a hot research topic of scholars at home and abroad.

Acknowledgments

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