A Review of Control Strategy of the Large-scale of Electric Vehicles Charging and Discharging Behavior

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Abstract. Large scale access of electric vehicles will bring huge challenges to the safe operation of the power grid, and it's important to control the charging and discharging of the electric vehicle. First of all, from the electric quality and network loss, this paper points out the influence on the grid caused by electric vehicle charging behaviour. Besides, control strategy of electric vehicle charging and discharging has carried on the induction and the summary from the direct and indirect control. Direct control strategy means control the electric charging behaviour by controlling its electric vehicle charging and discharging power while the indirect control strategy by means of controlling the price of charging and discharging. Finally, for the convenience of the reader, this paper also proposed a complete idea of the research methods about how to study the control strategy, taking the adaptability and possibility of failure of electric vehicle control strategy into consideration. Finally, suggestions on the key areas for future research are put up.

1. Introduction

Electric cars have great environmental advantages [1], which has attracted large attentions and favour of countries and companies related[2]. In the future, large-scale electric vehicle uncertain charging behaviours will have some influence on the security and reliability of power grid system [3], such as the overload caused by charging, which can not be ignored. Domestic and international researches on electric vehicle charging load are numerous. Literatures [4-15] established different electric vehicle load models to research the influence of electric cars on the power grid. To ensure the safe operation of power grid and improve the capability of carrying large-scale charging load, electric vehicle charging behaviours need normative regulation and guidance [16]. For example, through the policy and energy price guidance, electric vehicles can charge orderly. Thus it can reduce the peak load and ensure the safe operation of the power grid. At present, domestic and international researchers have conducted extensive studies on electric vehicle charging and discharging control, and put forward intelligent charging control methods and the vehicle-to-grid (V2G) strategy on electric vehicle charging and discharging.

This paper analysed electric cars charging impact on power grid. Then it has consolidated various researches on electric vehicle charging and discharging control strategy at home and abroad, which has provided a reference for readers.

2. Impact of Charge Load on the Network

Due to the uncertainty of charging time, starting time and charging power [17], access of large-scale electric vehicles to the grid may have a great influence on equilibrium of load, quality of electric power, economy of power grid and etc. [3].Firstly, large-scale charging behaviours of electric cars will cause load increasing highly. In the discorded charging cases, it will enlarge the load difference between peak and valley, which will need extra power to meet charging load requirements [18-19]. Secondly, terrible charging load may increase the voltage deviation [20-23] to cause the asymmetry of three-phrase voltage [24, 25] and incremental losses of distribution network [26, 27]. Thus, economic loss could be made. In addition, due to the nonlinear load, vast harmonic caused by electric cars charging will do harm to no-load loss, lifespan, etc. of transformers [28-31].

Researches above show that discorded charging behaviours of electric cars may have a bad effect on the safe, reliable and economic operation of power grid. Therefore, effective guidance and control to charging behaviours of electric cars can reduce some bad influence on the grid.

3. Electric Vehicle Charge Control Strategy

According to different control modes, charging and discharging control strategies are summarized into two categories, direct control and indirect control. Both of the modes can conduct effective control of charging and discharging of electric cars, and reduce bad effects on power grid.

3.1 Direct control

Direct control mode means conducting regulation that of time, power and etc. to charging and discharging of electric cars via charging devices. Thus, charging and discharging of electric cars can be well-organized.

Literature [16] based on the driving rules and charging modes of electric buses and cars, set up different charging time, avoiding the disordered charging peak and natural power using peak overlap effectively. Literature [32] confined charging conditions. Available charging time is from 6 p.m. to 7 a.m. next day. During this time, electric cars are allowed to charge when load is below 40 percent. On the basis above, it set up the limitation of charging power according to different available charging time. Literature [33] divided 1 day into 96 periods according to forecasting time intervals of load. It proposed a local optimum charging strategy by optimizing charging schemes of accessed electric cars at the end of each period. Literature [34], regarding charging power of charging stations of each time as control targets, set up an optimal scheduling model and found optimized charging schemes of the next day, which intended to curb load fluctuations and reduce load valley difference.

Charging control strategies above are conducted by control charging power or starting time of each electric car and charging station directly, which put forward a higher requirement for hardware devices and dispatchers of the grid [35]. And strategies above have some deficiencies on actual operations for not taking users' charging benefits and convenience into consideration.

3.2 Indirect control

Indirect control mode means using economic and technical methods to guide users to charge orderly instead of limiting users' charging power or time. It includes two ways, the first is using price policies, minimized charging costs and etc. to guide users' charging behaviors, and the second is making electric cars and new power access to the grid or participated in ancillary services, ensuring optimized operation of power grid.

Based on time of use price, literature [36-41] considered the lowest charging cost as a goal to develop the optimal charging plan. Literature [42-44] considered servicers minimum cost and maximum benefits as goals to set up the optimal charging and power purchasing plans. Literature [45] targeted at users' minimum cost and considered the limitation of battery characteristics and multi-constraints, build up an optimized charging model of electric cars based on TOU and using heuristic algorithm to find optimized charging control strategies. Literatures [46, 47], according to users' feedback on electricity price, proposed a determining method of price to guide users to charge during the valley period. Literatures [48, 49] showed that we can guide users to charge at the low load period, which effectively decreases the grid load peak. Through setting up the electric vehicle owners for different periods of peak response model, literature [50] modified the regulation of the point when starting to charge and drew grid load curve at a specific peak period of policy. Finally the paper proved the role the orderly charging plays in load shifting in practical example. According to the load of different cities, literature [51] determined the optimal low prices period and finally proposed an orderly slow charge strategy.

The new energy and electric vehicles entering the network has influence on the network. In order to alleviate the side effect, literatures [52-55] considered the relationship among the three aspects and proposed the orderly charge strategy in view of network with new energy plugged in. The results of [55] showed that reducing overload and drop problem caused by electric vehicle fast charge by the renewable energy is available. Literature [52] constructed grid-user control bilayer structure which is targeted at stabilizing load fluctuations and improving the utilization of new energy in the grid layer and select the optimal charging power. Taking the fairness of user charging and the range of power grid coordination as assessment indicators, the research proposed a weighted power allocation formula and set up a complete grid-user orderly charge strategy. Considering the system with wind power and electric vehicles, [53, 54] studied the influence of charge control on curbing the fluctuation of wind output and improving the wind power consumption. Literature [45] took coefficient of variation which reflects the dispersion degree of electric vehicles and wind power total output as the target function and built a dynamic coordinated control model between cars and wind power output. Literature [56] took wavelet neural network to predict the real-time price and set up a model at the target of the minimum charge costs and impact. Finally, the study proposed the policy to utilize the photovoltaic power in electric car charging stations.

Moreover, as mobile energy storage unit, electric vehicles can provide support of active and reactive for system load and generators spinning reserve and take part in system frequency regulation ancillary services and optimized operation of the grid [57,58]. Literature [59] studied the method of electric vehicles involved in FM in the management mode of 'Decentralized access, Centralized control'. The research, taking the lifespan of battery as one of constraint conditions, assessed the capacity of electric vehicle and built the static frequency characteristic model of electric vehicle charging and discharging in centralized management of electric vehicle with adjustable capacity. According to the demand of drive, literature [60] proposed the strategy the electric vehicles participate in frequency management.

4. Research Ideas

Recently, there are lots of methods studying the electric vehicle charging control strategy. However, most studies failed to carry out the adaptability analysis of the proposed strategy and failed to consider the problem that the strategy may become invalid. Based on the disadvantages, the article proposes an idea from reality, which fully considered the probability of failing, in order to help readers better understand the process of the study and practice on the charge control strategy. The research idea is shown as follows:

1) Analyse the influence electric vehicles have on the network and its causes.
2) Propose corresponding solution to the causes.
3) Select the appropriate charge control strategy and calculate the access load of each network node, according to the strategy.
4) Analyse the adaptability of the strategies and compare the feasibility of them. Propose to modify the current charging control strategy.
5) When the strategy fails, analyse the planning of the charge facility or the construction of the network and propose the improved opinions.

The detailed process is illustrated in the figure 1.

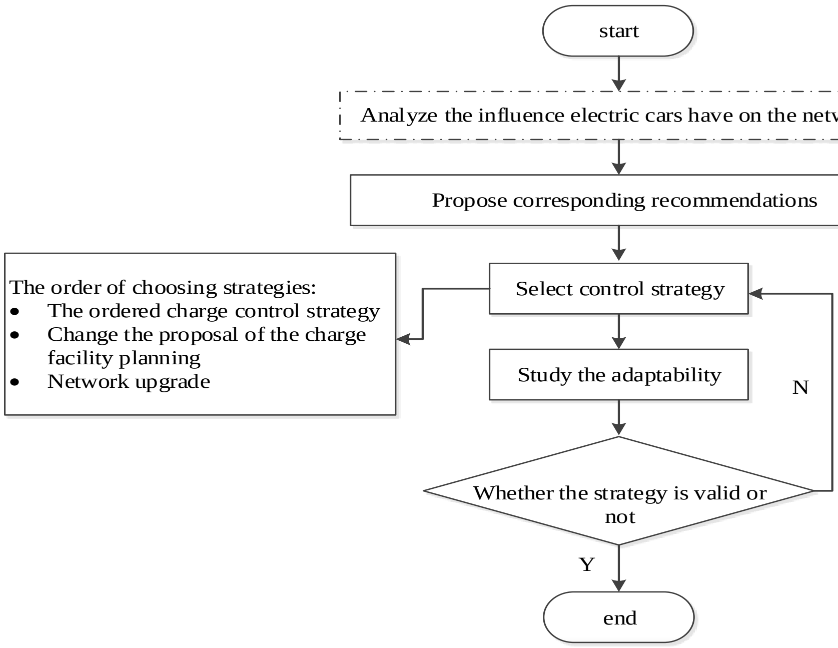

Figure 1. The detailed process of studying control strategies

5. Summary

This article summarizes the current research status in two aspects —— the influence electric vehicles charging and discharging have on the network and the control strategy of charge. The recent researches mostly focused on the intelligent charge model which is based on the temporal distribution and failed to consider the real condition of the network. What's more, all the control strategies were proposed on the basis that electric vehicles can be controlled directly and lacked the consideration of its feasibility. Meanwhile, in the optimization of the charge behaviors, its influence on batteries hasn't been taken into account. Then the paper offers the suggestions on the research point, to provide reference for the further study.

1) When studying the charge of electric vehicles, we should combine the real condition of network with the locating of electric cars.
2) In the optimization of the study, we should consider the lifespan of electric vehicle battery, safety of the network, the benefit of the users and the convenience of charge.
3) Take deep discussion of decomposition and coordination of electric vehicle charging and discharging process and apply the control strategy to every electric car to verify the feasibility of study.
4) Discuss the function of charge control as the approach to support the running and control of the system.

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