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Improvement and Implementation of Electric Vehicle Charging Optimization Strategy Based on Multi-body Dynamics

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Abstract: The charging time and location of electric vehicles have certain randomness and uncertainty. The disordered charging will bring new challenges to the power grid, affect the stability of the power system, and reduce the power quality. Therefore, it is particularly important to study the charging optimization strategy of electric vehicles. The purpose of this paper is to study the improvement and realization of electric vehicle charging optimization strategy which depends on multi-body dynamics. This paper establishes a charging load model for electric vehicles. Combined with the vehicle travel statistics released by the Transport Development Research Institute, the charge demand of electric vehicles is simulated using the Monte Carlo method. It is found that it is not conducive to the economic and stable operation of the distribution network, and the higher the share of electric vehicles, the more significant the adverse impact. Genetic algorithm is used to solve the optimization model. The peak and valley periods are subdivided by the membership function. The response model of electric vehicle is established through price elasticity matrix, and the optimized peak valley time of use price is finally solved by using genetic algorithm. Finally, the multi-body dynamics model is used for simulation.

1. Introduction

In terms of energy conservation and emission reduction, even though electric vehicles have such great advantages, they still have not achieved industrialization. The uneven development of various technical indicators of electric vehicle power batteries is the fundamental reason for restricting the development of electric vehicles. Their charge discharge ratio is small, and the charging time is strictly limited. The battery is often under charged or overcharged, which will damage the internal structure of the battery in the long run and greatly shorten the service life of the battery. In practical application, many batteries are not worn out, but are charged out. This virtually increases the use cost of electric vehicles and is not conducive to the mass production and promotion of electric vehicles. To sum up, a reasonable and efficient charging control method and charging device have been developed through multi-body dynamics to maximize the efficiency of the battery and extend its service life to the maximum extent, which ultimately has a substantial role in promoting the mass production and promotion of electric vehicles[1-2].

In the research on the improvement and realization of the electric vehicle charging optimization strategy relying on multi-body dynamics, many scholars have studied it and achieved good results. For example, Liu F M, based on power electronics technology, analyzes the different harmonics and impact on the power grid caused by different charging and discharging voltages of electric vehicles under different conditions [3]; Tang JY, based on the existing harmonic theory research, combined with the Monte Carlo simulation method, has constructed a harmonic model that conforms to the electric vehicle charging and discharging process. At the same time, the mathematical derivation of the harmonic current generated is carried out. In addition, the analysis shows that different charging modes will cause different levels of harmonic pollution to the power grid [4].

This paper establishes a charging load model for electric vehicles. Combined with the vehicle travel statistics released by the Transport Development Research Institute, the charge demand of electric vehicles is simulated using the Monte Carlo method. It is found that it is not conducive to the economic and stable operation of the distribution network, and the higher the share of electric vehicles, the more significant the adverse impact. Genetic algorithm is used to solve the optimization model. The peak and valley periods are subdivided by the membership function. The response model of electric vehicle is established through price elasticity matrix, and the optimized peak valley time of use price is finally solved by using genetic algorithm. Finally, the multi-body dynamics model is used for simulation.

2. Research on Improvement and Realization of Electric Vehicle Charging Optimization Strategy Relying on Multi-Body Dynamics

2.1. Analysis of Electric Vehicle Charging Mode

Analyzing the charging characteristics of electric vehicles is a prerequisite for modeling the disordered charging load, and the charging characteristics of electric vehicles are mainly reflected in three aspects: charging mode, charging power and vehicle type. In order to meet the charging needs of different types of vehicles, the charging modes of electric vehicles are mainly divided into the following three types: conventional slow charging, fast charging and wireless charging. Each charging mode is described as follows [5-6]:

(1) Conventional slow charging

This mode does not require high power supply, and the charger and its installation cost are relatively low. It can make full use of the valley price period to charge, reduce the charging cost, and is more flexible in the choice of charging time, which is more suitable for places with high density such as unit parking lots and residential communities.

(2) Fast charging

The fast charging mode usually adopts the pulse fast charging method, which can greatly shorten the charging time, accelerate the reaction speed of chemical materials during charging, reduce the polarization phenomenon, and then increase the battery capacity, increase the battery capacity, and improve the starting performance [7-8].

Advantages of fast charging. Disadvantages of fast charging: the charging current is too large, which increases the power grid loss and destroys the operation stability, and the load of local distribution network is easy to rise rapidly; the construction cost of fast charging stations is very high, and the corresponding cost of fast charging is higher than that of conventional slow charging. Generally, fast charging stations will charge additional charging service fees.

Fast charging is applicable to taxis, buses and a small number of private cars in urgent need of supplementing electric energy with large daily mileage and short charging dwell time. This mode is generally carried out in large fast charging stations, not in homes or ordinary parking lots. For fast charging, the rated capacity of the transformer in the area shall also be considered to avoid overload operation [9-10].

(3) Wireless charging

At this stage, the power of wireless charging is low, which is not much different from that of conventional slow charging. It takes 5-8 hours to fully charge the electric vehicle. Although the wireless charging mode is fast and convenient to use, this technology is not yet mature and is still in the stage of exploration and research. A lot of work needs to be done before large-scale promotion. With the development of the charging technology and the continuous improvement of supporting facilities, combined with the rapid construction of smart grid in China, the application of wireless charging mode will be greatly promoted [11-12].

2.2. Analysis of the Impact of Electric Vehicles on the Power Grid

Considering the national conditions of our country and the current research situation of pure electric vehicle technology in our country, the development of pure electric vehicles is relatively basic and promising. For a large oil importing country like China, there are relatively severe environmental problems. The practice of mass production and application of pure electric vehicles has great advantages, which are mainly shown in the following three points: (1) Reduce dependence on oil and gas resources. China's crude oil has reached 2.5% in 2015 ×10t, expected to reach 3.5 in 2020 × 10t Due to the increase of domestic material level, the corresponding automobile industry is also developing constantly. At present, most of the motor vehicles are internal combustion engines, and the energy consumed is gasoline or diesel, which has accounted for the majority of imported oil. Therefore, the popularization of pure electric vehicles can slow down the consumption of crude oil and reduce the import of crude oil. (2) Further reduce environmental pressure Due to the continuous development of domestic industry, environmental problems have seriously affected the lives of residents, and China is currently a major global auto sales country. At present, the pollution caused by motor vehicles in the domestic environment has become the main culprit of air pollution. At present, the number of motor vehicles in China is still increasing, the impact on oil demand and environmental quality will continue to increase, and the environmental problems will become worse. Therefore, it is inevitable to develop pure electric vehicles. (3) Improve energy efficiency the energy utilization rate of gasoline and diesel used by internal combustion engine vehicles is relatively low, which does not reach the maximum energy utilization. According to the manufacturer's test, the energy waste of some vehicles reaches 60%. The use of pure electric vehicles will greatly alleviate this problem and improve energy utilization efficiency [13-14].

2.3. Implementation Plan

By default, the charging in the charging station is fast charging, and the charging in the residential area and the parking lot in the working area is conventional slow charging. The regional control center manages the fast charging piles of all fast charging stations within its jurisdiction and the charging piles of parking lots in residential areas and working areas. The charging pile continuously uploads the charging load of electric vehicles and the use of charging piles to the regional control center. The regional control center will, according to the overall distribution network load level, the current electricity price and the expected system state in the future, draw the best charging scheme in the area under its jurisdiction, and formulate the charging plan for each electric vehicle. When the operation reaches the time control node, The charging area control center will send the control plan of the electric vehicle back to the charger, update the charging state of the charger, and then realize the orderly charging of the electric vehicle in the area. The implementation scheme is shown in the following figure [15-16]:

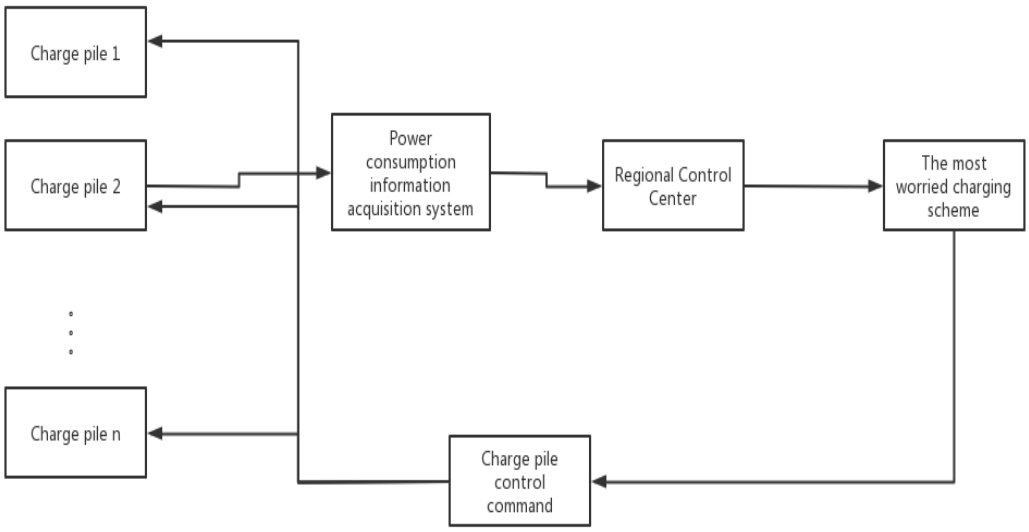

Figure 1. Implementation plan of the regional control center

2.4. Disordered Charging Model

The disordered charging of electric vehicles means that they will be charged immediately after arriving at the destination and will stop when fully charged.

The initial state of charge of the electric vehicle battery can directly affect the length of time required for the charging process. The calculation formula is as follows [17-18]:

$$SOC_t = \left(1 - \frac{R}{R_m}\right) \times 100\% \tag{1}$$

In Formula (1), SOCt is the initial state of charge of the battery when the electric vehicle is charged, R is the driving range of the electric vehicle, and Rm is the maximum driving range of the electric vehicle when fully charged. After the initial state of charge is obtained, the required charging time of the electric vehicle can be calculated:

$$T_c = \frac{(SOC_e - SOC_t) \cdot B}{\eta p} \tag{2}$$

In the formula, T is the time required for charging, SOCe is the user's expected power, and P is the charging power. The charging modes of private cars, taxis and buses are different, and the charging power is also different, which has been described in detail above and will not be repeated here. B is the battery capacity of electric vehicles. In this paper, it is assumed that the battery capacity of private cars and taxis is the same and 24kW ·h selected by most electric cars is used.

However, the battery capacity of buses is relatively large.

3. Research and Design Experiment on Improvement and Realization of Electric Vehicle Charging Optimization Strategy Relying on Multi-Body Dynamics

3.1. Regional Control Strategy

If the unified dispatching method of electric power companies is adopted, many problems such as low efficiency and scheduling errors may occur. This paper adopts the method of zoning control, and sets up different electric vehicle charging regional control centers in the city according to the division of districts to centrally control the charging arrangement plan of electric vehicles in the region. The charging process of electric vehicles is coordinated by the regional control center, and the dispatching center of the electric power company then uniformly manages the regional control center.

3.2. Experimental Design

This paper mainly studies and explores the improvement methods of the two electric vehicle charging optimization strategies studied in this paper. First of all, the significant improvement of orderly charging compared with disordered charging is studied through charging cost, charging time and corresponding load peak valley value. The second is the application of depolarization in vehicle charging and the optimization of electric vehicle charging.

4. Research and Experimental Analysis on Improvement and Realization of Electric Vehicle Charging Optimization Strategy Relying on Multi-Body Dynamics

4.1. Orderly Charging

This paper optimizes the disordered charging of electric vehicles at ordinary times, converts the disordered charging into ordered charging, and records the charging costs of the two charging methods, the peak valley difference of the charging load and the corresponding charging time. The experimental data are shown in Table 1.

Table 1. Cost, time and electricity consumption comparison of orderly charging and disorderly charging

	Charging cost	Load peak and valley difference	Charging interval
Disorderly charging	123512.4	36189.2	7
Orderly charging	72919.4	30119.2	3

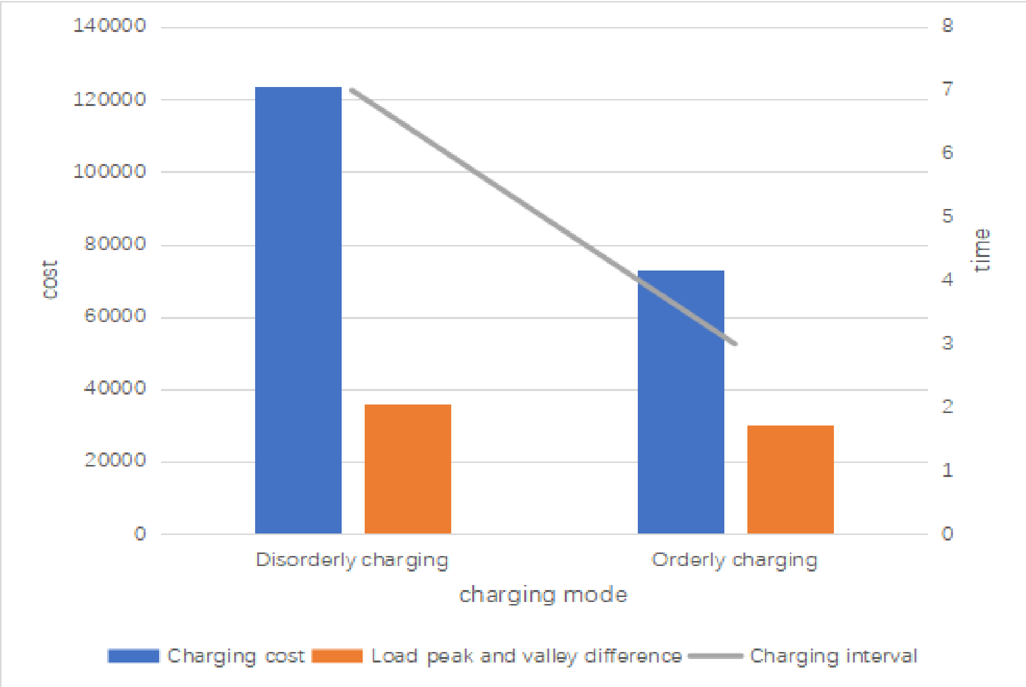

Figure 2. Comparison and difference between the two charging modes

It can be clearly seen from Figure 2 that the orderly charging optimized in this paper has greatly reduced the charging cost of electric vehicles by about 40%, and the related load peak valley difference has also been greatly reduced, which has more guaranteed the stability and safety of electricity consumption. At the same time, the corresponding charging time of electric vehicles has also been reduced by about 57%. Therefore, orderly charging is a necessary process to optimize the charging strategy of electric vehicles in the future.

4.2. Depolarization

This paper compares the charging time, temperature and corresponding SOC value of the traditional three-stage charging method with the depolarization side current charging method studied in this paper. Batteries of the same specification are mainly selected as the research object to ensure that the SOC value is 0% before the start of the experiment, and that the starting voltage and discharge ending voltage of the two charging methods are the same. The experimental data are shown in Table 2.

Table 2. Comparison of experimental data of three-stage charging method and variable current depolarization pulse charging method

charging method	charging interval	charge capacity	discharge capacity	volumetric efficiency
Three-stage charging method	5.4	22.14	7.4	67.3%
Changing current depolarization pulse charging method	4.01	10.12	7.12	90.43%

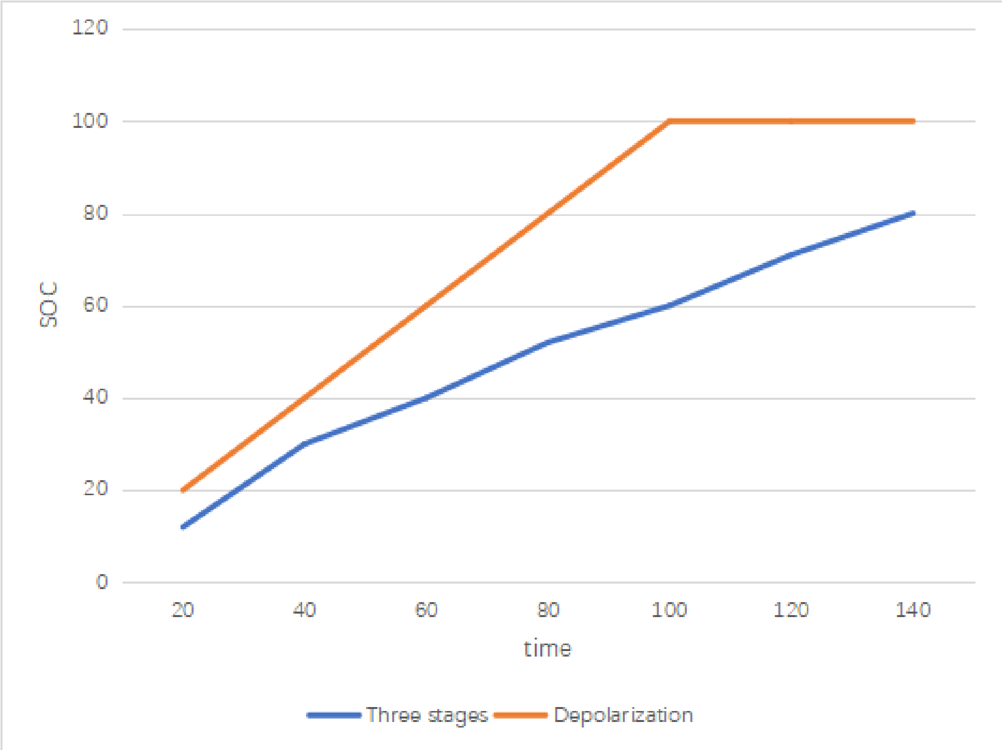

Figure 3. Battery SOC comparison during charging

It can be clearly seen from Table 2 and Figure 3 that the depolarization variable current pulse charging method proposed in this paper has a significant advantage over the traditional three-stage charging method. The charging speed is faster, which can save about half of the time. And the capacity efficiency has been greatly improved, from 67.5% to 90.29%.

5. Conclusion

The exhaust gas from traditional fuel vehicles is constantly affecting air quality and harming people's living environment. It is urgent to use electric vehicles instead of fuel vehicles. Electric vehicle is a kind of transportation tool with high energy efficiency and low carbon and environmental protection. It has incomparable advantages over traditional fuel vehicles in many aspects such as curbing global warming, energy conservation and emission reduction. The specific research results are as follows: Different types of electric vehicles are classified into private cars, taxis and buses. The charging modes and charging power of these three vehicles are analyzed respectively, and the charging load model of electric vehicles is established. Propose the electric vehicle charging zone control scheme, and uniformly coordinate and manage the charging load in the region through the charging zone control center.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Mehta R , Srinivasan D , Trivedi A , et al. Hybrid Planning Method Based on Cost-Benefit Analysis for Smart Charging of Plug-In Electric Vehicles in Distribution Systems. Smart Grid, IEEE Transactions on, 2019, 10(1):523-534. https://doi.org/10.1109/TSG.2017.2746687

[2] Meshram D B , Gohil V , Puri Y M , et al. Implementation of multi-objective Jaya optimization for performance improvement in machining curve hole in P20 mold steel by sinking EDM. World journal of engineering, 2022(3):19. https://doi.org/10.1108/WJE-11-2020-0568

[3] Liu F M , Bi S Y , Li B , et al. Implementation of a temperature bundle improves admission hypothermia in very-low-birth-weight infants in China: a multicentre study. BMJ Open Quality, 2022, 11(2):553-9. https://doi.org/10.1136/bmjoq-2021-001407

[4] Tang J Y , Guo W , Wang Y , et al. A co-simulation method for the train-track-bridge interaction analysis under earthquake using Simpack and OpenSees. Journal of Central South University, 2022, 29(8):2791-2806. https://doi.org/10.1007/s11771-022-5122-6

[5] Gampa S R , Jasthi K , Goli P , et al. Grasshopper optimization algorithm based two stage fuzzy multiobjective approach for optimum sizing and placement of distributed generations, shunt capacitors and electric vehicle charging stations. Journal of Energy Storage, 2020, 27(Feb.):101117.1-101117.13. https://doi.org/10.1016/j.est.2019.101117

[6] Dang H A , Dinh V B , Tong M Q , et al. A simulation-based multi-objective genetic optimization framework for efficient building design in early stages: application for Vietnam's hot and humid climates. International Journal of Building Pathology and Adaptation, 2022, 40(3):305-326. https://doi.org/10.1108/IJBPA-04-2021-0050

[7] Zaheer O , Ingarao G , Di Lorenzo R , et al. Study of the implementation of SPIF as a Reshaping strategy in terms of formability and accuracy performance. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 2022, 44(10):1-12. https://doi.org/10.1007/s40430-022-03779-2

[8] Wang P , Wang Y , Liu T , et al. Active learning-based multi-objective optimization for aerodynamic performance of a supercritical carbon dioxide turbine. Structural and Multidisciplinary Optimization, 2022, 65(9):1-16. https://doi.org/10.1007/s00158-022-03391-x

[9] Zhang Z , Chen Y , Tan L , et al. Torque Ripple Suppression for Permanent-Magnet Synchronous Motor based on Enhanced LADRC Strategy. Journal of Electrical Engineering & Technology, 2022, 17(5):2753-2760. https://doi.org/10.1007/s42835-022-01164-6

[10] Zhang H , Yao Y , Ma Y , et al. A 3D printing tool-path generation strategy based on the partition of principal stress field for fused filament fabrication. The International Journal of Advanced Manufacturing Technology, 2022, 122(3):1719-1735. https://doi.org/10.1007/s00170-022-09957-9

[11] Araz O . Optimization of three-element tuned mass damper based on minimization of the acceleration transfer function for seismically excited structures. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 2022, 44(10):1-14. https://doi.org/10.1007/s40430-022-03743-0

[12] Pratono A H . The strategic innovation under information technological turbulence: the role of organisational resilience in competitive advantage. Competitiveness Review: An International Business Journal, 2022, 32(3):475-491. https://doi.org/10.1108/CR-03-2021-0046

[13] Sammut-Powell C , Birleson E , Boaden R , et al. Scale-up of ABC care bundle for intracerebral haemorrhage across two hyperacute stroke units in one region in England: a

mixed methods evaluation of a quality improvement project. BMJ Open Quality, 2022, 11(2):117-71. https://doi.org/10.1136/bmjoq-2021-001601

[14] Raygor K P , Abla A A . Development of a customised programme to standardise comorbidity diagnosis codes in a large-scale database. BMJ Health And Care Informatics, 2022, 29(1):188-197-13. https://doi.org/10.1136/bmjhci-2021-100532

[15] Puntaier E , Hussain S , Onjewu A K E . The correlates of energy management practices and sales performance of small family food firms in Turkey. British Food Journal, 2022, 124(7):2343-2360. https://doi.org/10.1108/BFJ-08-2021-0945

[16] Cui A P , Samiee S , Zou S , et al. Exploration, exploitation, ambidexterity and the performance of international SMEs. European Journal of Marketing, 2022, 56(5):1372-1397. https://doi.org/10.1108/EJM-03-2021-0153

[17] Muller C G , Cruz A D , Canale F . Green innovation in the Latin American agri-food industry: understanding the influence of family involvement and business practices. British Food Journal, 2022, 124(7):2209-2238. https://doi.org/10.1108/BFJ-09-2021-0994

[18] Fleischer C , Charette K , Goodrum D , et al. Cognitive impairment and frailty screening in older surgical patients: a rural tertiary care centre experience. BMJ Open Quality, 2022, 11(2):125-32. https://doi.org/10.1136/bmjoq-2022-001873