

Research on Grid-Connected Charge-Discharge Control Strategy of Electric Vehicles Based on Clean Energy

Li Yang

College of Intelligent Manufacturing, Sanmenxia Polytechnic, Sanmenxia, Henan, China

Abstract:

Introduction: With the increasingly serious global energy shortage and environmental pollution problems, new energy vehicles have been widely concerned as a clean and efficient way of transportation. Among new energy vehicles, electric vehicles have become the mainstream direction of future transportation development with their advantages of zero emission, low noise and high efficiency. However, the popularity and large-scale application of electric vehicles need to solve the problem of energy management in the charging and discharge process.

Objectives: This paper studies the grid-connected charging and discharge control strategy of electric vehicles based on clean energy, aiming to realize the maximum utilization of clean energy and the stable operation of the power system.

Methods: This paper first introduces the basic principles and key technologies of grid-connected charging and discharging of electric vehicles, and then analyzes the application status and challenges of clean energy in electric vehicle charging. Then, this paper proposes a grid-connected charging and discharge control strategy based on clean energy. This strategy predicts the charging and discharge demand of electric vehicles and the output of clean energy, and makes a reasonable charging plan and discharge control strategy, so as to realize the maximum utilization of clean energy and the stable operation of the power system. Finally, the effectiveness and feasibility of the proposed control strategy are verified by simulation experiments.

Results: The experimental results show that this strategy can significantly reduce the impact of electric vehicles on the power grid and improve the benefits of clean energy while ensuring the stable operation of the power system.

Conclusions: In this study, the in-depth discussion and simulation experiment of the grid-connected charging and discharge control strategy of electric vehicles based on clean energy, and verified its effectiveness in balancing the grid load and optimizing the utilization of clean energy.

Keywords: clean energy, electric vehicles, grid-connected charge and discharge, control strategy, energy management.

INTRODUCTION

With the rapid development of the global economy and the growing population, the energy demand has risen sharply, while the excessive exploitation and use of traditional energy sources has led to serious environmental pollution and climate change problems. Therefore, finding and developing clean and renewable energy has become an important topic in today's world. Clean energy, such as solar energy and wind energy, has become the mainstream direction of future energy development with its renewable, pollution-free and sustainable advantages.

As a representative of new energy vehicles, electric vehicles have become an important trend of future transportation development with their advantages such as zero emission, low noise and high efficiency. However, the large-scale application of electric vehicles needs to address the energy management problems during their charging and discharging processes. The traditional power supply mode will not only cause an impact on the power grid, but also increase the load pressure of the power grid, which is not conducive to the stable operation of the power grid. Therefore, how to realize the grid-connected charge and discharge control of electric vehicles has become a hot spot and difficulty in the current research.

The grid-connected charge and discharge control strategy of electric vehicles based on clean energy aims to realize the maximum utilization of clean energy and the stable operation of the power system. By using clean energy to charge electric vehicles, the dependence on traditional energy can be reduced, reduce carbon emissions, and achieve green travel. At the same time, through the development of reasonable charging plan and discharge control strategy, the interaction between electric vehicles and the electric power system can be realized, the flexibility and reliability of the power system can be improved, the load pressure of the power grid can be reduced, and the stable operation of the power grid can be guaranteed.

This study will deeply explore the grid-connected charging and discharge control strategy of electric vehicles based on clean energy, analyze the application status and challenges of clean energy in electric vehicle charging, propose an effective control strategy, and verify its effectiveness and feasibility through simulation experiments. This study will provide strong technical support and theoretical basis for the popularization and large-scale application of electric vehicles, and make a positive

contribution to the utilization of clean energy and the stable operation of the power system. At the same time, this study will also provide useful reference and reference for the future research and development of new energy vehicles.

OBJECTIVES

This paper studies the grid-connected charging and discharge control strategy of electric vehicles based on clean energy, aiming to realize the maximum utilization of clean energy and the stable operation of the power system.

OVERVIEW OF THE INTERACTIVE CHARGING AND DISCHARGING SYSTEM BETWEEN ELECTRIC VEHICLES AND THE POWER GRID

Interactive charge-discharging system in the power grid (V2G, Vehicle-to-Grid), as a cutting-edge technology in the field of new energy vehicles, is gradually becoming an important bridge connecting energy transformation and transportation revolution. The system builds an integrated ecosystem of electric vehicles, the power grid, and advanced charge and discharge control technology. Its core is the realization of bidirectional energy flow between the EV and the grid: at night or during the grid load trough, the electric vehicle can recharge from the grid; during the daytime or peak load period, the EV can be used as a distributed energy storage unit to reverse discharge the grid and provide power support for the grid.

The emergence of V2G system not only helps to alleviate the contradiction between supply and demand of the power grid, improve the flexibility and stability of the power system, but also promotes the wide application of clean energy. Through V2G technology, electric vehicles can participate in the regulation of the power grid when not used, providing a buffer for the volatility of renewable energy sources (such as solar and wind energy), and promoting the optimization of the energy structure. In addition, V2G technology also provides consumers with additional revenue sources, such as participating in grid regulation services, further promoting the rapid development of the new energy vehicle industry.

KEY TECHNOLOGIES OF CHARGING AND DISCHARGING FOR THE INTERACTION BETWEEN ELECTRIC VEHICLES AND THE POWER GRID

The realization of interactive charging and discharging technology between electric vehicles and power grid depends on the breakthrough and innovation of a series of key technologies:

Bidirectional charge and discharge control technology: As the core of V2G technology, the bidirectional charge and discharge control technology requires the charge and discharge equipment to have precise power control and energy management functions. This includes the precise adjustment of the charging power, the optimized control of the discharge process, and the real-time monitoring of the charge and discharge state. Through the advanced algorithm and hardware design, the two-way charge and discharge control technology ensures that electric vehicles can maintain efficient and stable operation in the process of charging and discharge, and realizes the two-way efficient conversion of energy.

Collaborative control of battery Management System (BMS) and power grid: BMS is an important protection and management system for the battery pack of electric vehicles. It is responsible for monitoring the voltage, current, temperature and other key parameters of the battery pack to ensure that the battery operates within a safe range. In V2G system, BMS needs to deeply cooperate with the grid control system and optimize the charge and discharge strategy according to the demand of the grid and the state of the battery. This includes the control of the battery charge and discharge depth, the regulation of the battery temperature, and the monitoring of the battery health status, to ensure the safety and reliability of the battery in long-term use.

Interaction between smart grid technology and electric vehicles: Smart grid technology can realize real-time monitoring and intelligent dispatching of the grid, and improve the stability and economy of the grid. By interacting with electric vehicles, smart grids can manage power load more effectively and optimize the allocation of power resources. For example, the smart grid can make real-time scheduling according to the charging and discharging requirements of electric vehicles to ensure the stable operation of the grid; Meanwhile, the electric vehicles can also be used as a distributed energy storage unit to participate in the regulation service of the grid to improve the flexibility and reliability of the grid.

Information security and data protection technology: V2G system involves a large number of data transmission and information interaction, so information security and data protection are very important. The advanced encryption technology and identity authentication technology can ensure the data security and operation security of the system. This includes encryption of data transmission, authentication of user identity, and control of system access to prevent malicious attacks and illegal access.

CHALLENGES AND PROBLEMS OF CHARGING AND DISCHARGING DURING THE INTERACTION BETWEEN ELECTRIC VEHICLES AND THE POWER GRID

Although V2G technology has broad application prospects and significant social and economic benefits, it still faces some challenges and problems in practical application:

Technical standards and compatibility: There are differences between electric vehicles and charging and discharging equipment produced by different manufacturers in terms of communication protocols and data formats, resulting in poor compatibility between systems. This increases the difficulty of system construction and operation and maintenance, and limits the wide application of technology. In order to promote the standardization and large-scale application of V2G technology, it is necessary to establish unified technical standards and norms to promote the cooperation and exchanges between different manufacturers.

Adaptability of power grid infrastructure: As the number of electric vehicles increases, the power grid needs to be upgraded and transformed to meet the grid-connected charge and discharge needs of large-scale electric vehicles. This includes improving the power grid access capacity and enhancing the stability and security of the power grid. In order to support the development of V2G technology, the grid needs to accelerate the pace of intelligent transformation and upgrading to improve the flexibility and reliability of the grid.

Battery performance and life: The performance and life of electric vehicle batteries are important factors affecting their grid-connected charge and discharge applications. Frequent charge-discharge operations may accelerate battery aging and degradation, reducing battery life and performance. In order to extend the service life of batteries and improve the charge and discharge efficiency of batteries, it is necessary to strengthen the research and optimization of battery materials, battery management system and charge and discharge control strategy.

Economy and market acceptance: the construction and operation and maintenance costs of V2G system are relatively high, and users also have doubts about the uncertainty of discharge income. These factors limit the economics and marketing of the technology. In order to promote the wide application and development of V2G technology, the joint efforts of the government, enterprises and users are needed. The government can introduce relevant policies to support the development and application of V2G technology; enterprises can strengthen technological innovation and industrial upgrading; and users need to improve the awareness and acceptance of new technologies.

To sum up, the interactive charging and discharging technology of electric vehicles and power grid is one of the key technologies to realize the deep integration of new energy vehicles and power grid. However, challenges such as technical standards, grid infrastructure, battery performance, and economic and market acceptance still need to be addressed in practical applications. In the future, with the continuous progress of technology and the continuous support of policies, it is believed that the interactive charging and discharging technology of electric vehicles and the power grid will be more widely used and developed, injecting new vitality into the energy transformation and transportation revolution.

METHODS

TYPES AND CHARACTERISTICS OF CLEAN ENERGY

Clean energy, also known as green energy, refers to the energy that does not emit pollutants and can be directly used for production and living. The development and utilization of this kind of energy is of great significance to alleviating environmental pressure and realizing sustainable development. Clean energy mainly includes solar energy, wind energy, hydrogen energy, biological energy, ocean energy and water energy. As shown in Table 1.

Table 1 Clean energy Type Table

Clean energy types	description	Use the form	merit
solar energy	Convert the suns solar energy into heat energy, electrical energy, or chemical energy	Light to heat conversion (solar water heater, solar stove); light and electricity conversion (solar panels, solar car and boat)	Environmental protection, safe, pollution-free, renewable

wind energy source	Use wind power generation or as power directly drive mechanical devices	Wind power generation; wind water pump, etc	Less investment, high efficiency, economic durability, renewable
hydrogenic energy	The energy produced by hydrogen combustion is only water and a small amount of hydrogen nitrogen	As a fuel use	Good thermal conductivity, high heating value, good combustion performance and clean
biological energy source	The energy of solar energy stored in living organisms in the form of chemical energy	Into solid, liquid and gaseous fuels (e. g. waste fuel)	Renewable, reduce environmental hazards
ocean energy	Including tidal energy, wave energy, ocean current energy, seawater temperature difference energy and seawater salinity difference energy	Power generation, power supply, etc	Renewable, small impact on environmental pollution, great potential
hydroenergy	The kinetic energy, potential energy and pressure energy of water bodies	hydraulic electrogenerating	Renewable and clean energy is an important part and widely used

APPLICATION STATUS OF CLEAN ENERGY IN ELECTRIC VEHICLE CHARGING

With the rapid development of the electric vehicle industry, the application of clean energy in electric vehicle charging is becoming increasingly widespread. This Table 2 clearly shows the energy sources, charging objects, main characteristics, and the challenges or limitations of the different types of charging stations.

Table 2 Charging station type table

Charging station type	energy sources	Charging object	main features	Challenges / Limitations
Solar charging station	solar energy	electric vehicle	Using solar panels to convert solar energy into electricity is environmentally friendly and reduces charging costs	Relying on weather conditions, the charging efficiency decreases at night or on cloudy days
Wind energy charging station	wind energy source	electric vehicle	Combined with wind farms, the electricity generated by wind power is charged	The construction site is limited (in areas with rich wind resources), and wind energy fluctuations affect the stability of charging
Hydrogen charging station	hydrogenic energy	Fuel-cell electric vehicles	Provide hydrogen as fuel, suitable for fuel cell electric vehicles	Hydrogen energy production, storage and transportation costs are high, and the technology

				maturity needs to be further improved
Integrated energy charging station	A variety of clean energy sources (such as solar, wind, hydro, etc.)	electric vehicle	Combined with a variety of clean energy, improve energy efficiency, reduce the dependence on a single energy	Construction and operation complexity is high, the need to coordinate the operation of different energy systems

In addition, with the development of smart grid technology, clean energy and ev charging have become closer. Smart grid can realize real-time monitoring and intelligent dispatching of the grid, and optimize energy distribution according to the needs of the grid and ev charging. This makes the application of clean energy in electric vehicle charging more efficient and flexible.

The energy conversion efficiency of clean energy is the key factor that affects its application effect in electric vehicle charging. The conversion efficiency of solar panels is affected by various factors such as light intensity and temperature, while wind power generation is also limited by natural conditions such as wind speed and wind direction. All these factors lead to the conversion efficiency of clean energy is not high enough, which affects its practical application effect in electric vehicle charging.

The construction of clean energy charging stations requires a large amount of money and technical support. Especially in some remote areas or rural areas, the construction of clean energy charging stations is more difficult due to the weak infrastructure. In addition, the access and dispatch of clean energy charging stations to the existing power grid also need to solve a series of technical problems, which further increases the difficulty of construction and operation.

The supply of clean energy is often intermittent and unstable, such as wind and solar power, etc. This poses challenges to the energy supply stability of clean energy in electric vehicle charging. To solve this problem, large-scale energy storage systems need to be built to balance energy supply and demand, and thus ensure the stable operation of clean energy charging stations.

The construction and operation costs of clean energy charging stations are relatively high. This is mainly due to the high manufacturing cost of clean energy equipment, and the waste of energy conversion efficiency of clean energy. In addition, clean energy charging stations also need to consider the cost of energy storage and transportation, which makes them face some economic pressure in practical application.

At present, the application of clean energy in electric vehicle charging is still lack of unified policy and standard support. Policy differences and inconsistent technical standards in different countries and regions have affected the popularization and development of clean energy charging stations. In order to promote the application of clean energy in electric vehicle charging, more clear and unified policies and standards need to be formulated to guide and support the construction and operation of clean energy charging stations.

To sum up, the application of clean energy in electric vehicle charging has broad prospects and potential. However, a range of technical and economic problems need to be addressed to achieve the widespread use of clean energy in ev charging. With the continuous progress of technology and the continuous improvement of policies, it is believed that the application of clean energy in electric vehicle charging will make more significant progress.

GRID-CONNECTED CHARGING AND DISCHARGE CONTROL STRATEGY OF ELECTRIC VEHICLES BASED ON CLEAN ENERGY

The core of the grid-connected charging and discharge control strategy of electric vehicles based on clean energy is to optimize the charging and discharge process of electric vehicles, so as to realize the maximum utilization of clean energy and the stable operation of the power system. This strategy regards electric vehicles as mobile energy storage units, and, through intelligent management and control, realizes the collaborative interaction between electric vehicles and the power grid and the clean energy power generation system.

First, this strategy needs to make full use of the advantages of clean energy, such as photovoltaic power generation, such as renewable, clean and pollution-free, and easy access to light energy, to provide electricity for electric vehicles. By combining

electric vehicles with photovoltaic power generation system and then connecting them to the distribution network, the impact of large-scale charging of electric vehicles on the distribution network can be effectively weakened, the indirect carbon emissions of electric vehicles can be reduced, and the real "zero emission" can be realized. At the same time, this strategy can also absorb photovoltaic power generation locally, reduce the phenomenon of "abandoning light", and help solve the problem of grid connection.

Secondly, this strategy should be based on the mobile energy storage characteristics of electric vehicles, and realize the efficient utilization of energy through reasonable charge and discharge control. For example, when photovoltaic power generation is sufficient, photovoltaic power is used to charge electric vehicles, and electric vehicles are discharged as a distributed power source if necessary to relieve the pressure of the grid during peak hours.

Finally, the strategy should also consider the stability and safety of the power system. Through real-time monitoring of the state of the power grid, electric vehicles and clean energy generation, a reasonable charge and discharge plan is formulated to ensure the balance of supply and demand and stable operation of the power system.

Charge and discharge demand prediction of electric vehicle is the key link in formulating the control strategy. The forecasting methods mainly include ev charging load forecasting based on short-term load forecasting method, Monte Carlo simulation method and other new ev charging load forecasting methods.

The charging load forecasting of electric vehicles is based on the short-term power load forecasting method, and the charging load demand of electric vehicles can be predicted by combining the historical charging behavior data of electric vehicles and referring to the short-term load forecasting method in the power system load forecasting. This method can be divided into traditional prediction methods based on mathematical tools and modern prediction methods combining research results in the field of artificial intelligence.

Monte carlo simulation law is based on the national residents travel survey of traffic behavior database, based on the Monte carlo principle, through the simulation owners traffic habits (including travel habits and charging habits), establish a mathematical model with random probability characteristics to predict the future time charging time, place, load demand.

Other new ev charging load prediction methods include mathematical method using dynamic differential equation, ev load prediction method based on energy equivalence, and improved ev charging load calculation model with coupling characteristics based on nuclear density function. These methods have their own advantages and disadvantages, and appropriate prediction methods should be selected according to the actual situation.

Accurate ev charging and discharge demand prediction can provide strong support for the formulation of charging plan and discharge control strategy.

Clean energy output prediction is another key link in formulating the grid-connected charging and discharge control strategy of electric vehicles. Clean energy mainly includes photovoltaic power generation, wind power generation, etc., and its output is random and intermittent, so it is necessary to be accurately predicted.

Photovoltaic power generation output prediction can be modeled and predicted by historical data, weather forecast and other information, using machine learning, deep learning and other algorithms. The output prediction of wind power generation can be predicted by the monitoring and analysis of meteorological data such as wind speed and wind direction, combined with the physical characteristics of wind turbines.

The accuracy of clean energy output prediction is crucial to developing charging plans and discharge control strategies. Through accurate prediction, the charging and discharge time of electric vehicles can be reasonably arranged to ensure that clean energy should be used to charge electric vehicles when clean energy output is sufficient, and electric vehicles can be discharged as distributed power sources to the grid when necessary.

Based on the charging and discharge demand forecast of electric vehicles and the clean energy output forecast, the charging plan and discharge control strategy of electric vehicles can be formulated.

The charging plan should be comprehensively considered according to the charging demand of electric vehicles, the output of clean energy, the load status of the power grid and other factors. When the clean energy output is sufficient, clean energy is used to charge the EV, reduce the charging power during the peak load, and the energy storage characteristics of the electric vehicle can be used to discharge the grid.

The discharge control strategy should take into account the energy storage state of electric vehicles, the demand of the power grid and the driving demand of electric vehicles. During peak grid load or insufficient, the EV can be used as a distributed power source to discharge the grid, the energy storage condition of the EV should meet the driving demand.

By formulating a reasonable charging plan and discharge control strategy, the synergistic interaction between electric vehicles and the power grid and the clean energy power generation system can be realized, and the energy utilization and the stable operation of the power system can be optimized.

RESULTS

In the simulation experiment, we observed the following results. This Table 3 clearly shows the different parts of the simulation experiment, the experimental results, and the corresponding analysis:

Table 3 Results and Analysis of charging and discharge control strategy of electric vehicles

Experimental part	experimental result	analyse
Optimization of EV charge and discharge behavior	In the scenario of sufficient clean energy output, electric vehicles give priority to using clean energy for charging, and the charging behavior is highly concentrated in the periods of strong light or sufficient wind power. During the peak period of the power grid load, some electric vehicles are dispatched to discharge to the power grid, effectively alleviating the pressure of the power grid.	The control strategy has successfully realized the optimization of the charging and discharging behavior of electric vehicles, which not only meets the charging needs of electric vehicles, but also makes full use of clean energy, and reduces the burden of the power grid.
Clean energy utilization rate has been improved	As the charging and discharging behavior of electric vehicles is intelligently dispatching, the utilization rate of clean energy is significantly improved. Especially in the case of large fluctuation of clean energy output, the energy storage characteristics of electric vehicles play a role in smooth output and reduce the waste of clean energy.	The control strategy effectively improves the grid connection rate and utilization rate of clean energy, promotes the large-scale application of clean energy, and reduces the dependence on traditional energy.
Power grid load regulation effect	During the peak load period, EVs discharge as a distributed power source, effectively reducing the peak load; during the low load period, the charging behavior of EVs is moderately delayed or restricted, reducing the load fluctuation of the grid.	The control strategy has a significant effect on regulating the power grid load, and contributes to the stable operation of the power grid and energy saving and emission reduction. At the same time, this regulation also improves the flexibility and resilience of the grid, providing possibilities to meet more uncertain challenges in the future.
Stability and reliability assessment	In the case of a large number of electric vehicles or insufficient output of clean energy, although the control strategy shows	The control strategy performs well in most cases, but still needs further optimization under extreme conditions. Future

	certain fluctuations, it can still maintain the stable operation of the power grid on the whole. However, in some extreme cases, such as the sharp decline in clean energy output caused by extreme weather, the stability of control strategies is challenged.	research should focus on how to maintain the stability and reliability of control strategies in extreme situations, for example by introducing more energy storage devices or developing more advanced prediction algorithms.
--	--	---

DISCUSSION

Although the control strategy performs well in most cases, further optimization under extreme conditions. Future research should focus on the following aspects:

- (1) strong prediction accuracy: improve the prediction accuracy of clean energy output and grid load to better guide the charging and discharge behavior of electric vehicles.
- (2) Introduce more energy storage: consider introducing more energy storage devices into the system, such as battery energy storage system (BESS), to meet the challenges of insufficient clean energy output and peak grid load.
- (3) Optimized control algorithm: develop more advanced control algorithm to maintain the stability and reliability of the control strategy under extreme conditions.

With the popularization of electric vehicles and the development of clean energy, the grid-connected charge-and-discharge control strategy of electric vehicles based on clean energy has a broad application prospect. Through continuous optimization and improvement, the strategy is expected to make an important contribution to achieving the energy transition, promoting sustainable development and responding to climate change. At the same time, the implementation of this strategy will also promote the coordinated development of the smart grid and the new energy vehicle industry, and provide strong support for the construction of a greener, low-carbon and intelligent energy system.

Finally, we need to consider more practical factors. In the simulation experiment, we mainly consider the charging and discharge behavior of electric vehicles, the output of clean energy and the load change of the power grid. However, in practical application, more practical factors need to be considered, such as the driving demand of electric vehicles, the behavior habits of the owners, the safety constraints of the ower grid, etc. These factors may have important effects on the performance of control strategies and therefore need to be considered and analyzed in subsequent studies.

To sum up, the grid-connected charge-discharge control strategy of electric vehicles based on clean energy has a broad application prospect and an important practical significance. Through continuous optimization and improvement, we can further improve its performance and stability, and make a greater contribution to the realization of sustainable development and green energy utilization.

REFERENCES

[1] Wang Yubo. Hybrid battery energy storage configuration and scheduling method to promote the consumption of new energy. Wuhan University, 2021.

[2] Deng Shicong, Hu Ran, Ye Wenzhong. Distribution network cable status evaluation technology based on built-in conductor temperature measurement. High Voltage technology, 2020,46(12):4430-4434.

[3] Peter M ,A. H G ,Saim M .Theoretical and Experimental Analysis of a New Intelligent Charging Controller for Off-Board Electric Vehicles Using PV Standalone System Represented by a Small-Scale Lithium-Ion Battery.Sustainability,2022,14(12):7396-7396.

[4] Mojtaba P ,Saeid E ,Morteza A .Increasing the Penetration of Electric Vehicles in Distribution Networks Using Optimal Charging/Discharging Control and Reactive Power Support in the Presence of Nonlinear Loads.International Transactions on Electrical Energy Systems,2022,2022

[5] Giorgio B ,Ettore B ,Andrea M , et al.Impact of bidirectional EV charging stations on a distribution network: a Power Hardware-In-the-Loop implementation.Sustainable Energy, Grids and Networks,2023,35

- [6] Chaowanan J .Optimal techno-economic sizing of a standalone floating photovoltaic/battery energy storage system to power an aquaculture aeration and monitoring system.Sustainable Energy Technologies and Assessments,2022,50
- [7] Megaptche M A C ,Kim H ,Musau M P , et al.Techno-Economic Comparative Analysis of Photovoltaic Panel/Wind Turbine/Hydrogen Storage, Photovoltaic Panel/Wind Turbine/Battery Systems for Powering a Simulated House including Hydrogen Vehicle Load at Jeju Island .AFORE,2023,