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Adaptive Genetic Algorithm for Scaling New Energy Vehicle Charging Models

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ABSTRACT: *With the growth and progress of the country's economic strength, people's travel levels are continuously improving. Traditional fuel-powered vehicles tend to produce more volatile pollutants during driving, negatively impacting the ecological environment and resource utilization. This paper uses adaptive genetic algorithms to analyze the scale of the new energy vehicle's intelligent charging process. It explores the optimal design approach for intelligent charging stations using this algorithm. Firstly, the computation and modelling process of the adaptive genetic algorithm isanalysed to address the issues of difficulty and slowness in charging. In-depth discussions are conducted on power transmission, power management, charging paths, and other aspects using monitoring mathematical models. A filtering algorithm is used to optimize the adaptive genetic algorithm and construct a solution model for intelligent charging control strategies. Finally, the optimal design strategy of car charging stations under intelligent induction is studied. The results show that the adaptive genetic algorithm has good effects in optimizing the intelligent charging strategy of new energy vehicles and the intelligent control design of charging stations.*

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1. Introduction

Various preferential policies for new energy vehicles have gradually improved, and the government encourages the public to purchase new energy vehicles by launching a series of purchase financial subsidies, exemption of purchase taxes, etc. [1]. Some first-tier and developed cities have also adjusted the quotas for fuel vehicles, promoting people's inclination towards using new energy vehicles. However, new energy vehicles are easily affected by battery motivation during actual driving, and the incomplete charging facilities and the lag of battery charging systems will limit the promotion of new energy vehicles. To further promote the utilization and frequency of new energy vehicles, optimizing charging strategies and charging station facilities is a major concern for practitioners in the field of new energy vehicles [2]. In real life, the distribution of public charging stations is not reasonable. Many areas show uneven and scattered distribution, and even if charging stations are found, long queues for charging make it very difficult to achieve rapid charging. Therefore, although using new energy vehicles saves energy costs, it consumes more time. This is also a major issue limiting car owners from purchasing new energy vehicles, which hinders the promotion and popularization of new energy vehicles in society [3].

The intelligent charging strategy is a key aspect of battery management and use in new energy vehicles. Intelligent charging is also a new idea to transform traditional energy transmission, allowing electrical energy to be effectively utilized in network digitization. This intelligent transformation is based on network technology, cloud sharing, deep learning technology, etc., to create an intelligent and practical charging system [4]. The intelligent charging control system can improve the operation efficiency of new energy vehicles and achieve resource allocation and regulation in different spaces and times [5]. The intelligent charging method brings greater convenience to people's lives, and new energy vehicles provide users with intelligent, safe, convenient, and efficient services. In addition, we also understand the reasons for the construction of intelligent charging for new energy vehicles. Firstly, the demand for charging capacity of new energy vehicles is large, which is the main problem many new energy manufacturers have solved. In major public places and private commercial areas, the construction of garages did not consider the charging problem of new energy vehicles. Therefore, the power surplus and charging demand are the main reasons limiting the use of new energy vehicles [6]. The concept of power expansion is to add new power supply lines to equipment that meets the electricity demand based on monitoring of power equipment and provide new energy vehicles with power sources by installing intelligent charging devices that do not conflict with the actual line. It can be seen that there are still many obstacles in the promotion of new energy vehicles, and the intelligent charging strategy of vehicles is also a core part of changing the development of new energy vehicles.

1.1. Adaptive Genetic Algorithms

The genetic algorithm is a traditional intelligent bionic system that evolves based on the natural genetic evolution processes of living organisms, exhibiting robust capabilities for global optimization. An adaptive genetic algorithm is found to offer potential benefits in TSP applications.[7]. It exhibits a superior ability to achieve optimal energy utilization and realize noteworthy cost savings compared to the alternatives that underwent evaluation.[8]

AGA is used to optimize the backpropagation neural network(BPNN), which has high localization accuracy while improving the data processing ability [9]. Many adaptive multi-objective optimization genetic algorithms have been developed. For example, in [10], authors proposed an ANN predictive model for thermal energy consumption in institutional buildings.

In Adaptive Genetic Algorithms, the probabilities of mutation and crossover, along with the selection process, are continuously adjusted during the algorithm's execution. [11] The adaptive genetic algorithms are not only effective for simulating maps of different sizes and obstacle arrangements but also demonstrate outstanding performance, including significantly decreasing the execution time of the algorithm program. [12, 13, 14] Additionally, the adaptive genetic algorithm can successfully address the limitations of the traditional genetic algorithm.[15]

2. Current Status of New Energy Vehicles and Intelligent Charging Technology Development

According to the survey, the new energy vehicle industry has received full support in various fields as a strategic new industry supported by the country. In the data statistics, we found that the annual production of new energy vehicles accounts for 1.2 times the total production of vehicles in the automotive field, with a significant growth rate compared to the previous year [16]. At the same time, in the sales field, more and more car owners favor the high performance, low price, and eco-friendly features of new energy vehicles compared to traditional fuel-powered vehicles, making them the preferred choice for daily commuting. From the perspective of city area distribution, new energy vehicles were initially widely used in developed cities in the south. With the promotion and popularization of new technologies, second-tier and third-tier cities have also started introducing new energy vehicles [17]. China's first batch of open cities and autonomous region cities are key areas for national development and support, and the sales performance of new energy vehicles in these regions has shown a year-on-year upward trend. Through the analysis of the development situation, various government departments have introduced more and more preferential support policies for new energy vehicles. In the action guidelines for carbon neutrality and peak carbon emissions issued by the country, the requirements for energysaving and emission reduction in various fields such as logistics, public transportation, and sanitation have been put forward. This situation greatly restricts traditional fuel-powered vehicles, making new energy-powered transportation popular in the current era [18].

The promotion volume of pure electric-assisted vehicles and hybrid power vehicles in the new energy is comparable. Through an understanding of the growth of motor vehicles, it is found that the growth rate of hybrid power vehicles is significantly lower than that of pure electric vehicles in the later stages. The per capita ownership index has also shown a year-on-year doubling coefficient growth. Although the subsidy effect on the purchase of new energy vehicles is getting lower, the technology and improvement of subsidies are not as good as in the initial stage, and people's enthusiasm for new energy vehicles remains unabated [19]. In terms of intelligent charging for new energy vehicles, the number of public and private charging stations that have been built and used is also increasing from the scarcity and scattered distribution of charging stations in the early stages to the later provision of charging services for new energy vehicles in every commercial and public place on average. This indicates that the advent of the intelligent charging era is much faster than the development and optimization of electric vehicle batteries. Before building an intelligent charging system, it is necessary to provide good technology and equipment to support its core functions. The quality of charging equipment and network communication issues have also impacted the intelligent charging control of new energy vehicles. Firstly, this intelligent charging technology is accomplished based on the joint work of hardware and software facilities, with hardware design referring to circuit circulation, transmission, etc. Various signals are collected and transmitted through current transport to the final intelligent control system, allowing car users and designers to know the charging status and battery capacity at any time. In the joint efforts of software facilities and hardware, intelligent charging already existed in the initial promotion of new energy vehicles. With a deep understanding of intelligent charging technology, it is found that network technology and strategy distribution algorithms are the prerequisites for creating timely and reliable charging facilities. It can ensure the safety and stability of charging facilities and improve charging efficiency, reducing time wastage for users waiting for charging. It can be seen that the development and promotion of new energy vehicles cannot be separated from the research on battery efficiency and intelligent charging strategies.

3. Intelligent Charging Control System and Optimal Charging Strategyfor Large-scale New Energy Vehicles

3.1. Intelligent Charging Optimization Control System for New Energy Vehicles

The high frequency of traditional fuel-powered vehicles used in the ecological environment and daily life has accelerated environmental pollution. Therefore, it is urgent to reduce the use of fuel-powered vehicles to protect the ecosystem. In the context of sustainable renewable energy, new energy vehicles have gradually entered the public's vision. However, new energy vehicles' charging efficiency, speed, and safety have become increasingly evident in the actual driving process. With the increasing use and popularity of new energy vehicles, charging and battery-related issues have also grown, especially in intelligent charging solutions and charging station construction and maintenance, which have become the main obstacles to promoting new energy vehicles. We conducted comprehensive and dynamic monitoring of the intelligent charging process and obtained its operational structure diagram, as shown in Figure 1.

From Figure 1, it can be observed that, first, multiple types of new energy vehicles are monitored during the charging process, and the status information of the vehicles is captured. Data information changes are integrated into the intelligent controller system when the new energy vehicles start or go into sleep mode. Ultimately, the battery status and input/output current status are determined to provide the car owner with an intelligent charging solution. The unorganized use of the power grid for charging large-scale electric vehicles has put pressure on the overall energy dispatch and planning control of the power system. During charging and discharging, the motor may cause the grid to reach its peak capacity, exceeding the maximum power supply capacity of the charging configuration network, leading to problems such

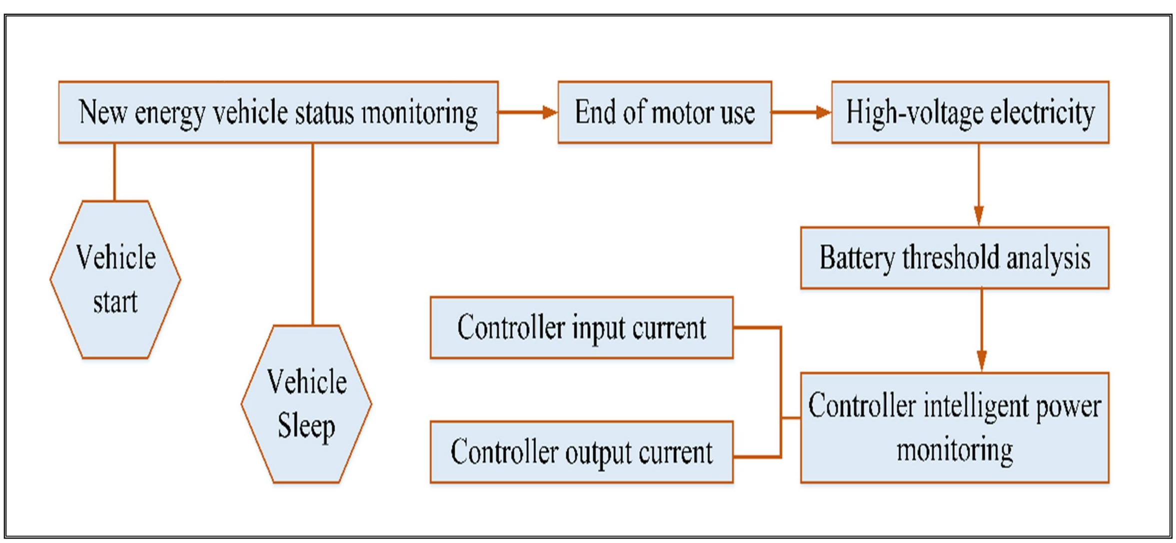

Figure 1. Structure Diagram of Intelligent Charging Process

as voltage rise and current overload. In terms of spatial allocation, the unorganized charging access also affects the transmission efficiency of current electricity, and this imbalance phenomenon poses significant risks to charging safety. Therefore, based on the above analysis, this paper uses the adaptive genetic algorithm to explore the intelligent charging strategy for new energy vehicles. First, an adaptive genetic algorithm-based intelligent charging optimization model is established, and the charging plan for new energy vehicles throughout the day is randomly divided into several periods. The first new energy vehicle charging start is taken as the independent variable for calculation, and the minimum standard deviation of load energy is taken as the control variable:

$$\min \sqrt{\frac{1}{T} \times \sum_{u=1}^{E} [\sum_{j=1}^{N} (X_t \times P_E) \times \eta]^2} \tag{1}$$

The formula represents the number of new energy vehicles randomly charged within a day and compares and analyzes the total charging time. The dynamic change of the independent variable is connected with the rated charging power of the new energy vehicle, and the calculation results express the charging efficiency. To meet the charging needs of new energy users, we also need to establish constraints in the model:

$$0 \le SOC_j^{io} - SOC_0 \le \frac{\sum_{i=1}^{ts} (x^e \times p_E^i) \times \eta}{C^i} \tag{2}$$

In the equation, SOC represents the initial state of charge for each new energy vehicle, which calculates the average battery capacity inside the vehicle based on the charging time and quantity. This constraint behavior ensures that the charging amount of the vehicle reaches at least the expected peak value when the charging process is completed. This adaptive network system for intelligent charging monitoring integrates the collected charging data, device status, and energy changes to assess and analyze various aspects of new energy vehicles, ultimately helping users reduce the energy consumption of new energy vehicles.

3.2. Design of Intelligent Charging Station Strategy for New Energy Vehicles

The traditional automotive industry, which relies primarily on petroleum as the main fuel, has significantly increased the demand for fossil fuels in the national economy, exacerbating the contradiction between energy industry production and economic distribution. The increasingly severe global climate change has also received widespread attention from countries, and there is a growing demand for a clean and beautiful ecological environment. People urgently need environmentally friendly, energy-saving, and emission-reducing means of transportation. With their strong environmental protection capabilities, cleanliness, and high energy utilization efficiency, new energy vehicles have become breakthrough in addressing the above issues . Although new energy vehicles have a strong competitive edge, they still face serious challenges in the promotion process, mainly due to the incomplete construction of their main charging facilities. Insufficient charging station quantity,low charging efficiency, and difficulties in achieving charging intelligence are common issues. Compared to traditional petroleum-fueled vehicles, the main resistance to promoting new energy vehicles lies in the difficulty of batteries meeting long-distance travel demands. People living in major cities often need multiple charging sessions to meet their daily life and work needs. Compared to the five-minute refueling time for traditional vehicles, the several-hour charging time for new energy vehicles is more noticeable regarding its limitations. Additionally, due to the efficiency and optimization issues of charging stations, queuing for charging during peak traffic periods has discouraged many potential buyers.

To address the above situation, this paper adopts an adaptive algorithm to study the charging strategy for new energy vehicles and optimise charging stations. The adaptive genetic algorithm is an evolutionary search algorithm inspired by the evolutionary process in biology. By performing selection, extraction, crossover, mutation, and other operations, it outputs the optimal solution by selecting variables that best fit the maximum fitness in the evolution process. Simple genetic algorithms only use fixed probabilities for extraction and crossover calculations, ignoring the judgment of the adaptive characteristics of the population, which affects the ability of global search and traversal and is irreversible. Therefore, when using the adaptive genetic algorithm to study the intelligent charging strategy for new energy vehicles, we also incorporate a filtering algorithm to reduce the model’s error coefficient and assist in the intelligent design of charging stations. The improved adaptive genetic algorithm extraction and mutation formulas are as follows:

$$P_{\max} - \left(\frac{p_{\max} - p_{\min}}{M} \right) \times Den, fit > fit_{avg} \tag{3}$$

In the equation, *P* represents the calculation’s maximum crossover probability of data. When the iteration reaches the desired intelligent charging effect, the model can automatically stop to reduce energy consumption.

4. Scale New Energy Vehicle Intelligent Charging Control System and Optimal Charging Station Strategy

For intelligent control of new energy vehicle charging, managing charging equipment is a key factor in achieving convenient and fast charging. The battery and charging management content includes control of charging stations, charging systems, and other aspects. However, from the perspective of the current charging management system, the overall charging system is not yet perfect. Although it can automatically start charging and stop when full, with features like power failure protection and billing memory, the charging process lacks high-level, efficient, unified intelligent management. This may lead to many dangerous factors, especially during severe weather conditions such as thunderstorms when unauthorized charging operations occur. In this paper, the adaptive genetic algorithm is incorporated into the research on intelligent charging strategies for new energy vehicles, utilizing the random search nature of the adaptive algorithm to find suitable charging modes for any environment. Before starting the algorithm, the charging environment of the adaptive genetic algorithm is set, and the maximum initialization and iteration times are calculated. The best-fitted individual is selected and saved, and the computation is stopped if the target output reaches the optimal result. 800 new energy vehicles are randomly selected as data algorithm test samples, and the user's frequency of using the power grid is also included. Considering practical scenarios, we only analyze the automobile charging load index variation between the traditional and intelligent charging strategies under the adaptive genetic algorithm.

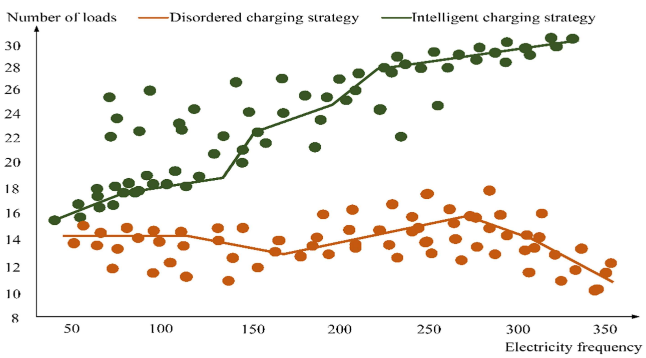

Figure 2. Comparison of Power Load between Two Charging Strategies

As shown in Figure 2, in the traditional unstructured charging strategy, the peak load of new energy vehicles occurs less frequently, leading to poor utilization of power resources. By adopting the adaptive genetic algorithm optimized intelligent charging strategy, the efficiency of electricity load transmission can be improved, and the maximum peak value ensures better utilization of power resources, greatly assisting in the daily maintenance of the power grid. Subsequently, with the help of this algorithm, we optimized the design of the intelligent charging station's structure, mainly modifying modules such as touch screens, control systems, transmission systems, card reading systems, billing systems, and remote control. The intelligent charging station is also equipped with personnel identification and monitoring warning functions, which can enhance the efficiency of vehicle charging by identifying the identities of new energy vehicle users. The intelligent display screen and optimal charging strategy help users choose the appropriate charging mode. The charging module completes the battery charging and communicates with the new energy vehicle battery pack to control current, voltage, and temperature parameters. We compared the duration of vehicle owners' charging before and after using the intelligent charging station, as shown in Figure 3.

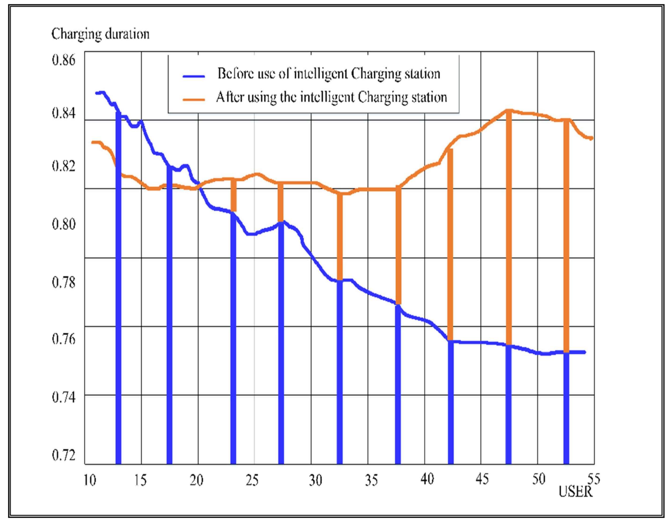

Figure 3 . Changes in Charging Duration before and after using the Intelligent Charging Station

As seen in Figure 3, the time consumed by new energy vehicle owners during the charging process significantly decreases after using the intelligent charging station. Therefore, intelligent charging strategies and stations can effectively enhance the battery management of new energy vehicles, ensure fast data transmission during driving, and help users monitor vehicle status changes in real-time.

5. Conclusions

Supported by renewable energy and environmental protection concepts, new energy vehicles have gradually become a substitute for traditional fuel-powered vehicles. Pure electric vehicles are the best-selling segment in the new energy vehicle industry, praised for their low energy consumption and minimal environmental pollution. However, issues such as battery capacity, charging efficiency, and charging station distribution in promoting and using new energy vehicles have always affected their acceptance. In this study, we analyzed the intelligent charging strategy for large-scale new energy vehicles using the adaptive genetic algorithm and researched the intelligent design of charging stations. We first used big data analysis to assess the current development status of new energy vehicles in battery management and conducted an in-depth analysis of intelligent charging concepts. We integrated the adaptive algorithm into the intelligent optimization strategy for charging, proposing a fast, convenient, safe, and adaptive charging mode. Finally, we optimized the adaptive genetic algorithm using a filtering algorithm and restructured the functionality of the charging station, combining intelligent technology with charging station design systems. The research demonstrates that the large-scale new energy vehicles based on the adaptive genetic algorithm have shown promising results in intelligent charging strategy optimization, and it also improved the utilization of charging stations, assisting new energy vehicle owners in addressing slow charging efficiency issues.

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