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New Energy Vehicle Development and Electricity Demand Forecasting Based on Random Forest Model

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Abstract. With the implementation of the green economy and the decarbonization strategy, the new energy automobile industry has developed rapidly in China, which poses new challenges to the balance and stability of the power system. This paper predicts the development trend of China 's new energy vehicle industry through the random forest model, and analyses the impact of the development of new energy vehicles on power demand. The results show that the number of new energy vehicles in China is expected to increase significantly, accounting for a quarter of the total number of vehicles, and the number of charging piles will increase significantly to meet the demand. With the development of the new energy automobile industry, the demand for electricity and power load in the whole society are expected to maintain rapid growth, which poses new challenges to the power supply stability of the power grid. This study provides an important reference for government regulation, power grid adaptation and new energy vehicle enterprise development planning.

1. Introduction

With the rapid development of China 's new energy automobile industry, the number of energy vehicles is increasing. Large-scale charging will make the total load of the power grid 'peak up', increase the burden of the distribution system, and further aggravate the contradiction between power supply and demand. On the one hand, considering the new challenges brought by the development of new energy vehicles to the balance and stability of power system, it is of great significance for government regulation and power grid adaptation to grasp the trend of the scale development of new energy vehicle industry and summarize the impact of new energy vehicle development and power demand. On the other hand, power resources are important input factors in the production process of new energy vehicles and their charging and swapping facilities. Studying the relationship between power and energy economic systems and the development of new energy vehicle industry is also of great significance for promoting the coordinated development of new energy vehicles with power and economy and optimizing the development plan of new energy vehicle enterprises.

Specifically, this paper uses the machine learning model to judge the trend of the scale development of the new energy automobile industry, and makes use of the advantages of random forest algorithm to make up for the prediction bias existing in the existing research, ensuring the accuracy of the analysis results, and further analyzes the comprehensive impact of China 's new energy automobile development on power demand.

2. Methods

Machine learning is an important technology to realize artificial intelligence. Random forest algorithm is one of the representative algorithms of machine learning. The random forest algorithm is known in industry and academia for its simplicity and efficiency, it is a decision tree-based classifier that selects the best classification tree by voting[1]. Random forest can realize the classification features of complex interactions, and the learning speed is fast. The results can be used for feature selection of high-dimensional data, which can overcome the shortcomings of complex classification rules, convergence to non-global local optimal solutions and over-fitting of decision tree, and the prediction error is small[2]. Given the advantages that random forests can limit the phenomenon of overfitting in machine learning and do not cause large errors due to small deviations, this study will use machine learning random forest method to predict the development scale of new energy vehicles.

3. Data

This paper uses China's new energy vehicle data and power consumption and power load data from 2014 to 2023. The specific data include the following: national car ownership, national new energy vehicle ownership, number of charging piles, annual electricity consumption, and 24-hour electricity load data on typical days.

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4. Results & Discussion

4.1.Multi-scenario prediction of new energy vehicles and charging and swapping facilities

This paper uses the random forest (RF) model to predict the national car ownership, new energy vehicle ownership, and the number of charging piles. This part takes the national car ownership prediction as an example. Firstly, the out-of-bag estimation of random forest (RF) model is used to evaluate the predictive ability of the model to variables. As shown in Figure 1, the horizontal axis is the number of decision trees (B), and the vertical axis is the out-of-bag error. It can be seen from the figure that when B>200, the error tends to be stable, and B continues to increase and will not decrease. Therefore, the model uses 500 decision trees to estimate, which has little effect on the fitting accuracy.

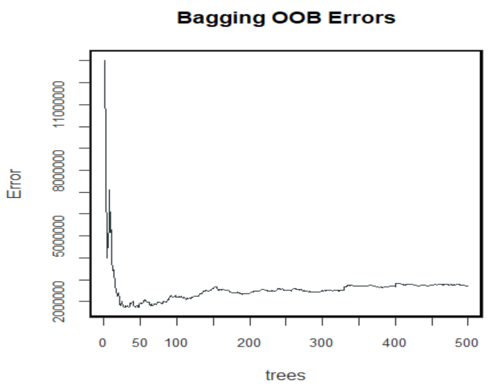


Figure 1. Out-of-bag estimation of national car ownership RF.

Secondly, the factors affecting the car ownership are sorted by the importance of the parameters. The results are shown in Figure 2. The first column of the important results of the variables in the output results (IncMSE) indicates the percentage of the increase in the out-of-bag error after removing a variable in the model (such as removing the variable age, the out-of-bag error increased by 15.68 %) ; column 2 (IncNodePurity) reports variable importance based on training sample calculations. From the diagram, it can be found that the two variables that have the greatest impact on the national car ownership are per capita GDP and population.

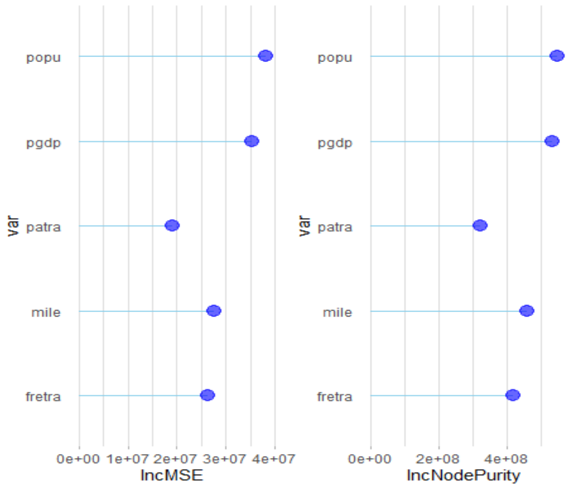


Figure 2. Importance ranking of prediction parameters of national car ownership.

Subsequently, model fitting was performed, and from the results in Figure 3, the model fitting results were better, and the adjusted R^2 all reached 0.99, indicating that the prediction results were more robust.

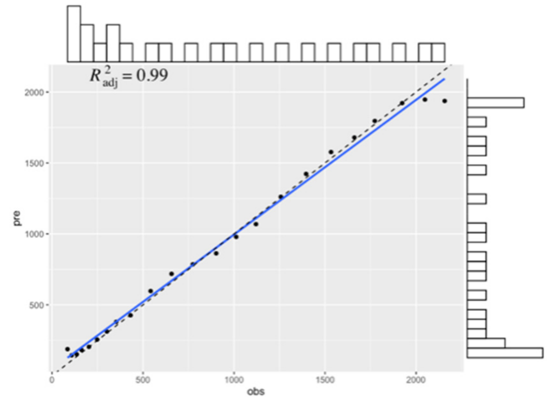


Figure 3. Fitting results of national car ownership prediction model.

The machine learning method is further used to predict new energy vehicles and charging facilities, and the results are shown in Table 1. According to the forecast results of the random forest model, in the development of new energy vehicles, the number of new energy vehicles in the country is expected to reach 103.25 million by 2030; at the same time, it is expected that by 2030, new energy vehicles will account for 25 % of total vehicles in the country.

Table 1. Prediction results of RF models such as new energy vehicle ownership in China.

	car ownership (10^8 counts)	new energy vehicles (10^4 counts)	charging pile (10^4 counts)	Public pile (10^4 counts)	Private pile (10^4 counts)	charging station (10^4 counts)
2023	3.34	2041	875	277	587	16.80
2025	3.78	4013	2483	596	1887	40.15
2030	4.17	10325	11253	1837	9416	178.5

Based on the current development of new energy vehicles and the change of market penetration rate, the future new energy vehicle ownership and penetration rate can be predicted, and the results are shown in Figure 4[3]. It can be seen from the figure that China 's new energy market penetration rate and China 's new energy ownership are on the rise. At this time, new energy vehicles occupy a large market share in China, and the rising share of new energy vehicles in the automotive market is conducive to the development of vehicle-network interactive technology.

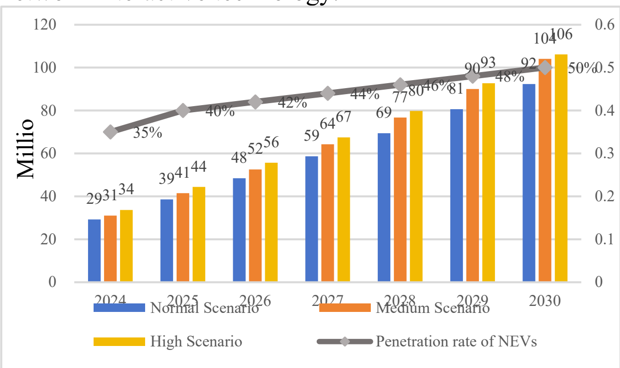


Figure 4. Prediction of new energy vehicle ownership and penetration rate in China.

4.2.Power demand forecast for new energy vehicle development

This paper collects typical daily electricity load data of typical private users and public charging piles, as shown in Figure 5.

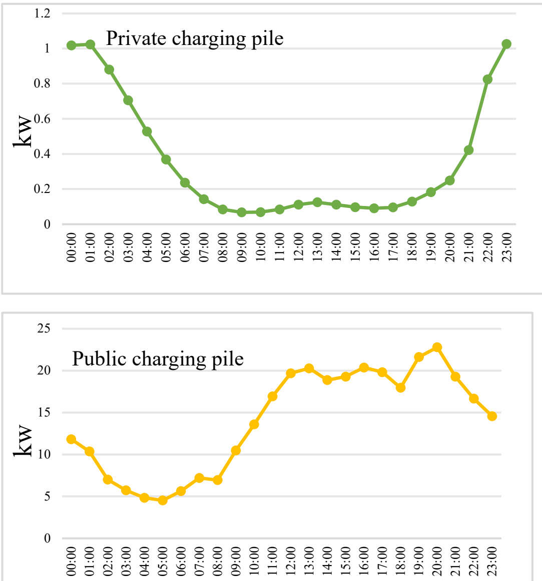


Figure 5. Typical daily electricity load data of private users and public charging piles.

From the typical daily load curve of individual residents' private charging piles, the valley of power consumption load appears in the daytime, and the power load is generally stable during the daytime. At 17:00, residents began to leave work. Some users began to charge directly after they arrived home, and the power demand for personal charging piles gradually increased. The charging peak of residents ' charging piles is from 22:00 at night to 2:00 the next day, which is related to the residents ' work and rest rules. After 0:00, as some users complete charging, the charging load of residents continues to decline, reaching the lowest point at 8:00 a.m. And continuing to remain in a relatively stable state.

From the typical daily load curve of a single public charging station, it can be seen that from 8:00, the demand for public charging piles gradually increases in the stage when residents gradually start to work. There is a small peak at 13:00, and at 17:00-20:00, the power demand of public charging stations is the largest, while the demand for electric vehicle public charging stations is the smallest in the early morning, and the difference is significant. At present, the layout of public charging stations is concentrated in living areas such as residential areas, shopping centers and work units. During the daytime work period, the power demand for public charging piles in the working area of residents has increased. In the evening, when residents leave work, the power demand for public charging stations in areas such as residential areas and shopping centers has increased.

In order to analyze the impact of new energy development on power consumption, this paper divides power consumption into two parts: traditional business power consumption and new energy power consumption. Figure 6 shows the electricity consumption of traditional and new energy vehicles in China.

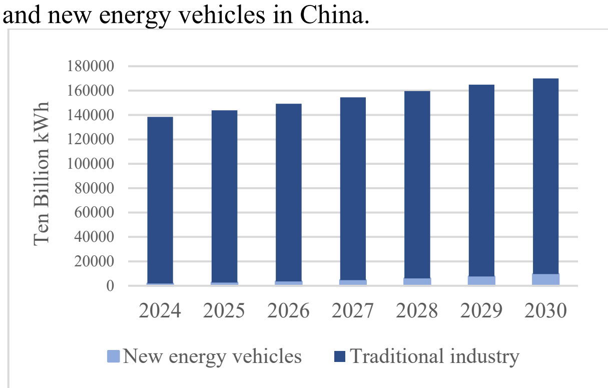
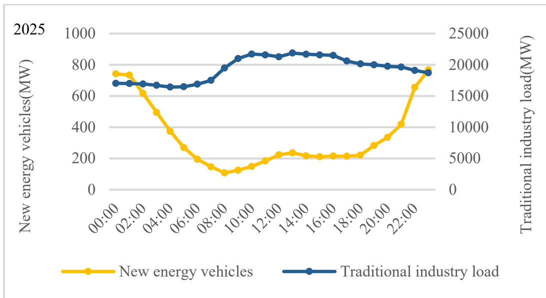


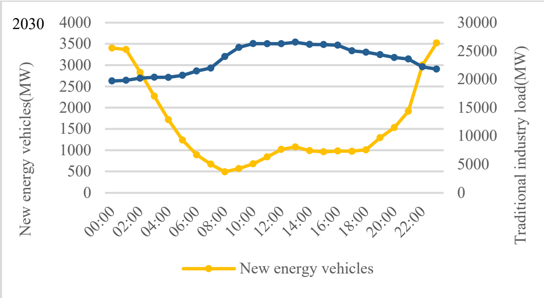
Figure 6. Electricity consumption of new energy vehicles and traditional industries.

From Figure 6, we can see that most of China 's electricity consumption comes from traditional industries, which shows that the main body of China 's electricity consumption is still traditional industries. With the rapid expansion of the new energy vehicle market, there have been significant changes in rapid growth from 2027 to 2030.This change shows the gradual popularization and acceptance of clean energy technology in the transportation field, as well as the increasing attention to environmental protection and energy efficiency[4].

Further, we predict China 's power load in 2025 and 2030. Figure 7 depicts the power load forecasting of traditional and new energy vehicles in China in 2025 and 2030.



(a)



(b)

Figure 7. Power load forecasting curve in 2025 and 2030.

It can be seen from Figure 7 that the traditional power load is the largest part of China 's power load in both 2025 and 2030. This shows the stable demand and sustainability of traditional industries in electricity consumption. This trend implies that in the next few years, traditional industries will still be an important factor to be prioritized in China's power supply and planning. It is worth noting that by 2030, the power load of new energy vehicles will increase significantly, which reflects the rapid expansion and technological progress of the clean energy vehicle market. This trend not only shows the impact of technological innovation on energy consumption structure, but also highlights the importance of clean energy in the field of transportation[5].

5. Conclusion

This study predicts the development trend of China 's new energy vehicle industry through the random forest model, and analyzes the impact of the development of new energy vehicles on power demand. The results show that by 2030, China 's new energy vehicle ownership is expected to grow significantly, accounting for a quarter of the total number of cars, while the number of charging piles will increase significantly to meet demand. In addition, by analyzing the impact of new energy vehicle charging behavior on grid load, it is found that the rapid rise of charging demand requires grid expansion, and the charging behavior overlaps with the peak of residential electricity consumption, which increases the pressure of grid dispatching. Furthermore, this paper predicts the power load in China in 2025 and 2030, and points out that the power consumption of new energy vehicles will increase significantly, reflecting the gradual popularization of clean energy technology in the transportation field. The research results show that with the development of the new energy automobile industry, the power demand and power load of the whole society are expected to maintain rapid growth, which poses new challenges to the power supply stability of the power grid. This study provides an important reference for government regulation, power grid adaptation and new energy vehicle enterprise development planning. It is expected that the power grid can not only deal with the impact of power supply stability caused by the increase of power load in time, but also achieve a win-win result.

Acknowledgments

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