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Analysis on influencing factors of EV charging station planning based on AHP

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Abstract. As a new means of transport, electric vehicle (EV) is of great significance to alleviate the energy crisis. EV charging station planning has a far-reaching significance for the development of EV industry. This paper analyzes the impact factors of EV charging station planning, and then uses the analytic hierarchy process (AHP) to carry on the further analysis to the influencing factors, finally it gets the weight of each influence factor, and provides the basis for the evaluation scheme of the planning of charging stations for EV.

1. Introduction

With the rapid progress of battery technology, EVs get more and more attention in recent years, and EVs have many positive effects on solving the present crisis of environment pollution and resources shortage.

At present, the development of the EV charging station is still in the demonstration and operational stage, the EV technology is increasingly developing, and the EV battery technology has improved greatly, with its unique advantages of high efficiency of charging and discharging, large output power and long service life, lithium-ion batteries are the most widely used in the electric car battery system now. However, the common charging time of EV batteries is too long (5 to 8 hours), and the mileage is limited after each charging, which is always the crux of the EV industry development [1]. EVs are not only a kind of load, but so can serve as energy storage for power grid, except that they have strong randomness, which is associated with the moving characteristic as a means of transport.

EVs can not only bring low carbon social economic prosperity, but also face many challenges, such as the social acceptability of EV launch in fossil-fuels-oriented energy economies, the cost of EVs: sales, long-life, and its decommission specifications/features-in the supplementary choices of recycling and reuse, etc. For the protection of EV battery systems, and lengthen the service life of the battery as far as possible, EVs should generally adopt the practice of conventional slow charging, in order to ensure the user for a long time and emergency driving demand, quick charge will be as a public service facilities and play an important complementary role in the road[2].

EV charging station planning problem directly determines the driving experience of EV users, and that also affect people's purchase intention to EV in a large extent, thus it affects the development of the popularity of EV and EV industry. The construction of the planning index system of EV charging

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station is very urgent, and it deeply affects the evaluation of the planning scheme of EV charging station [3].

The area of EV charging station planning has become a research focus, the literature [4] analyzed several factors that affecting electric vehicle charging station planning, and put forward the principle of its layout proposal, but it is short for quantitative analysis of the influence factors. Literature [5-7] put forward the planning method of EV charging station, but they are lack of systematic research for the influence factors that affecting the EV charging station planning. In conclusion, the related literature for systemic study on the influencing factors of EV charging station planning is less, and the related literature that considering the weight of every factor is much scarcer. This paper made a systemic in-depth research for the influencing factors of EV charging station planning with the application of AHP method, and studied their weights and provided the theoretical basis of the planning for EV charging stations in future.

2. Analysis on Influencing factors of EV charging station planning

The factors that affect the layout planning of EV can be summarized as the power system, transportation system, economic cost, user convenience and other factors [8].

2.1. Power system factors

Grid capacity factor is the main cause of capacity limit of the distribution network, and the charging current of general EV fast charging stations charger is large (up to 150A – 400A), and a charging stations is often equipped with more than one charger, so it is a huge load for the original grid, the grid capacity is one of the important factors that affect the layout planning of EV charging station.

Grid planning alignment refers to the blending degree of EV charging station planning and the network layout, especially the short to medium term planning of grid, can largely affect the EV charging stations within a period of time of planning, it can largely effect the EV charging station planning within a period of time[9].

In addition, a large number of EV that connected to distribution network will affect the power quality, reduce power supply reliability and cause a series of problems, so the consideration of these factors in the process of charging station layout of EV is also unavoidable.

2.2. Traffic system factors

Road congestion is an important factor restricting the layout of the charging station, and excellent EV charging station planning program should be selected that traffic congestion situation is relatively light zone.

Road network density affects the convenience of charging to a large extent, but also it can expand the scope of services to a certain extent.

2.3. Economic cost factors

EV charging station is an infrastructure construction. There is a large economic investment from the planning and construction to operation and maintenance, which also directly affect the choice of charging station planning. In this paper, the main economic cost factors are land cost, power grid reconstruction cost, operation and maintenance cost, etc.

2.4. Users' convenience factors

EV charging station is a kind of public service facilities, the users' charging convenience is particularly important, and this article mainly focuses on the service coverage and traffic convenience.

2.5. Other factors

The market share of EV industry is still very limited at present, and the present layout of the EV in the future will certainly experience reconstruction problems over a period of time, taking this factor into consideration within planning period will save costs for subsequent modification.

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Safety is very important to the long-term safe operation of the charging station[10], and it is an important factor to influence the selection of the planning scheme of the EV charging station.

EV technology maturity is also one of the key factors that largely affecting EV charging station planning, especially with the constant breakthrough of EV battery technology, the electric vehicle charging station layout should also adapt to the requirement of the EV battery.

3. Model construction

Analytic hierarchy process method (AHP) was proposed by the operational research experts T L Satty in the end of the 70s of the 20th century. As a kind of multi-objective decision method, AHP with a systematic and hierarchical features has been widely applied, especially some multi-objective, multi-criteria and lack of structural characteristics of relatively complicated problems [11].

3.1. Index system

First of all, the AHP logic level construction was made for the influence factors of the EV charging station planning, and the index system is built.

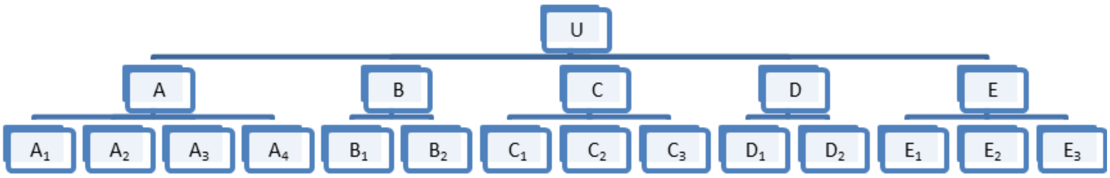

Figure 1. EV charging station planning impact factors analysis index system

Note: U-Influence factor analysis and others can be seen in table 4 and table 5.

3.2. Judgment matrix structure

After setting up the index system, a judgment matrix is constructed based on the index system, the values determined by contrast a hierarchy index important degree of influence on the upper indexes of every element in matrix[12], $b_{ij}=b_i/b_j$ said, the b_{ij} can use 0-9 said, see AHP relative importance of standard table.

Table 1. AHP relative importance of the standard

Scale	Meaning
1	b_i and b_j are equally important
3	b_i is slightly more important than b_j
5	b_i is more important than b_j significantly
7	b_i is more important than b_j strongly
9	b_i is extremely important than b_j
2、4、6、8	intermediate value of the judgment

3.3. Level sorting and consistency checking

After the establishment of the judgment matrix for each layer, the judgment matrix of each layer with the largest eigenvalue λmax and the corresponding eigenvector W is obtained, then the feature vector normalization, obtained in the same layer of each evaluation index compared with the rank weights of the upper one index importance. This process is single level sequencing. Random consistency index (CR) was used to measure the consistency of the decision maker's ideas.

$$CR = \frac{CI}{RI} \tag{1}$$

Where CR is the consistency ratio, CI is the consistency index of the judgment matrix, CI= (λmax-n) / (n-1), RI is the average immediately consistency index, and its value can be used to refer to the RI index table.

Table 2. Mean random consistency index

Order n	1	2	3	4	5	6	7
RI	0	0	0.52	0.89	1.12	1.26	1.36

For the matrix whose order number is 1 or 2, always has a complete consistency, therefore the RI value is 0, if matrix order number greater than 2, when the CR < 0.1 is considered the consistency of the judgment matrix meet the requirements, and it is in the reasonable scope, otherwise, it must be properly adjusted[13], and related formulas are as follows:

Each line element of the corresponding judgment matrix B is multiplied, and Mi is obtained：

$$M_i = \prod_{j=1}^{n} b_{ij} \qquad i = 1,2,3 \ldots \ldots n \tag{2}$$

Wi is Mi's n times square root obtained by calculation

$$w_i = \sqrt[n]{M_i} = \sqrt[n]{\prod_{j=1}^{n} b_{ij}} \tag{3}$$

Square root unit, we get the sort weight W_i:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{4}$$

The largest eigenvalue of the B matrix is calculated:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(BW)_i}{W_i} \tag{5}$$

In which，(BW)i means the first i element of vector BW.

4. A numerical example

The influence factors of EV charging station planning was analyzed by AHP, first of all， the judgment matrix for influence factors of sub reference layer is obtained. Hierarchical ordering and consistency checking were made according to the judgment matrix, finally we got the ranking of the reference layer and the corresponding weight of each layer. Results are shown in Table 3 shows.

Table 3. Sub reference layer factor weight table

Reference layer	Sub reference layer	Weight
A	A_1	0.439
	A_2	0.07
	A_3	0.23
	A_4	0.261
B	B_1	0.675
	B_2	0.325
C	C_1	0.594
	C_2	0.157
	C_3	0.249
D	D_1	0.683
	D_2	0.317
E	E_1	0.163
	E_2	0.54

E_3	0.297

In the same way, we calculated the influence factors and the weight of the reference layer, and the results are shown in the following table.

Table 4. Ranking factors of the reference layer

Target layer	Reference layer	Weight	Ranking	Factor name
	A	0.448	1	power system factors
	B	0.219	2	traffic system factors
U	C	0.109	3	economic cost factors
	D	0.083	4	user convenience factors
	E	0.141	5	Other factors

We got the overall order of the overall objectives for various factors combined with the above two parts, it can be seen that the grid capacity and road congestion are the most two important aspects. In addition in the selection of electric vehicle planning program， we should pay attention to grid capacity, road congestion, power supply reliability and power quality, etc. Rankings can be more intuitive to get from Figure 2.

Table 5. Weight table of influence factors

Index	Weight	Factor name
A_1	0.197	Grid capacity
A_2	0.031	Grid planning alignment
A_3	0.103	power quality
A_4	0.117	power supply reliability
B_1	0.148	Road congestion
B_2	0.071	Road network density
C_1	0.065	land cost
C_2	0.017	power grid reconstruction cost
C_3	0.027	operation and maintenance cost
D_1	0.057	service coverage
D_2	0.026	traffic convenience
E_1	0.023	Reconstruction and extension problems
E_2	0.076	Safety
E_3	0.042	EV technology maturity

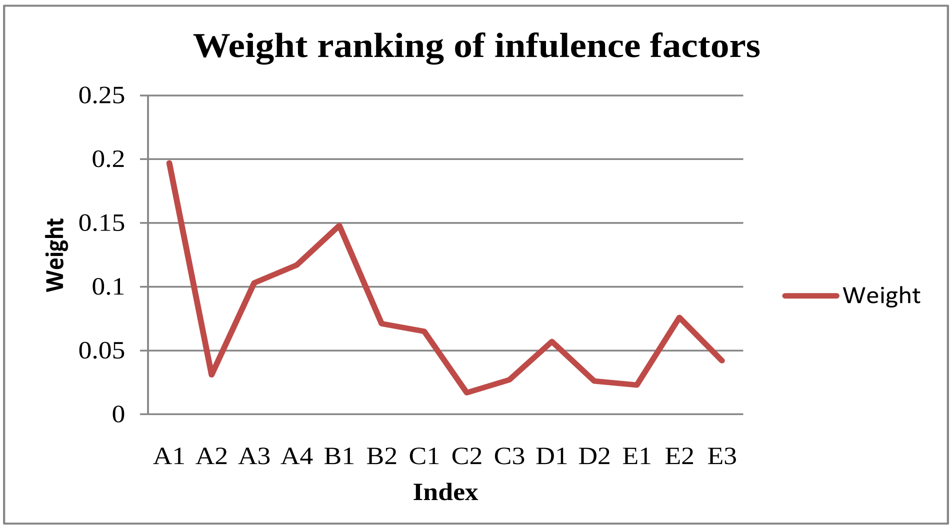

Figure 2. Weight ranking of influence factors

5. Conclusions

Reasonable EV charging station layout planning can provide electrical energy supplement better for users of EVs, and it is good for the safe operation of power grid, meanwhile it provides a strong guarantee for the smooth traffic network, it is of great significance for the popularization and promotion of EVs. There are many factors that affect the planning of EV charging station. In this paper, the main influencing factors are sorted by AHP, and the corresponding weights are obtained. It provides theoretical basis for the follow-up of the evaluation method of EV charging station.

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