Evaluation on Chinese and IEC Standards for EV Charging System using fuzzy TOPSIS method

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Abstract. In recent years, the rapid development of electric vehicle (EV) in China has played an important role in promoting the realization of carbon emission reduction and carbon neutrality in China. The EV charging standard directly affects the domestic and foreign sales of EVs, which is crucial to the sustainable development of the EV industry. This paper compares and analyzes the EV charging system standards in China and International Electrotechnical Commission (IEC), constructs a comprehensive evaluation index system for EV charging system standards, and builds a comprehensive evaluation model for EV charging system standards based on the fuzzy TOPSIS method. The comprehensive evaluation results of China and IEC EV charging system standards show that IEC standards as a whole are better than China's, but some indicators in China are better than IEC standards. The future development of China's EV charging system standards should be aligned with IEC international standards to further promote the international standardization of China's charging scheme.

1 Introduction

The charging interface is the most important component that connects EVs and power supply equipment during the charging process of EVs [1]. The unification of EV charging interface standards is of great significance to promote the promotion and application of EVs and the construction of charging infrastructure. Currently, governments around the world are actively exploring ways of the EV industry in response to the continuous growth of energy and environmental pressures, and have released and implemented their own EV development strategies, and initially formed a market development pattern represented by the European Union, the United States, Japan and China. With the rapid development of industry and technology, the role of standardization in promoting the industry has become increasingly prominent. From a global perspective, international technical standards have become the main basis for international trade arbitration. In order to make standards more conducive to their own technical solutions, countries are actively participating in the formulation of international standards. The standardization work of China's EV industry started late. In the early stage, it mainly adopted the method of introducing, digesting and absorbing international standards. With the support of the government and the rapid development of the industry, the international standardization work has also made great progress in recent years.

In 2014, China's DC charging scheme control guide circuit and charging interface technology, which was led by China Automotive Technology Research Center and

directly participated by State Grid Corporation of China, was formally voted by the International Electrotechnical Commission (IEC) and successfully incorporated into the IEC 61851 series, becoming one of the world's top three standard systems along with Europe, America and Japan. In October 2019, IEC formally agreed to include the Chinese AC charging system solution into the IEC61851-1 standard, but the working group experts still have different opinions on the interoperability issues that may arise from the coexistence of the Chinese AC charging system technical solution and the IEC solution. Therefore, in order to further promote the international standardization of EV charging systems, to make the IEC truly accept and approve the Chinese plan, and to clear obstacles to the export process of EVs, it is necessary to conduct an in-depth comparative study of the Chinese standards for EV charging systems and the IEC standards.

At present, some literature has already conducted comparative analysis and research on EV charging system standards. Ref. [2] studied the charging standards of EVs in Europe, America and Japan, and put forward policy recommendations for standardization. Ref. [3] analyzed the differences between domestic and foreign conductive charging connector standards, especially comparing the four indicators of charging mode, rated value, plugging force, and protection level, and proposed the requirements for standard compatibility. Ref. [4] studied the charging interface and standardization of EVs, focusing on the physical interface of the AC charging interface for EVs at home and abroad, but did not make detailed differences comparison on the

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compatibility of control pilot circuits, communication protocols, and domestic and foreign standards. Ref. [5] compared the interface structure, protection level, insulation resistance and dielectric strength, breaking capability, and heat resistance tests of DC charging systems and AC charging systems at home and abroad from the perspective of test requirements. The above documents have all studied the domestic and international standardization of EV charging systems, but most of them are mainly focused on the simple comparison of physical interfaces, there has not been a comprehensive evaluation and comparative analysis of China and IEC related EV charging system standards.

Therefore, this article conducts a comprehensive evaluation study on China and IEC standards for EV charging systems. Firstly, a comparative analysis of China and IEC standards for EV charging systems is carried out; Secondly, a standard evaluation index system for EV charging systems is selected, and a comprehensive evaluation model for EV charging system standards is constructed based on the fuzzy TOSPI method; Thirdly, a comprehensive evaluation is carried out on the standards of car charging systems; Finally, the main conclusions of this article are drawn.

2 Comparative analysis of China and IEC EV charging system standards

This article mainly studies China's national standards such as GB/T20234.1-2015, GB/T20234.2-2015, GB/T20234.3-2015 and IEC standards such as IEC 62196-1:2014, IEC62196 -2:2016 and IEC62196-3:2014, and focus on the comparative analysis of several key test items to clarify the advantages and disadvantages of the China's national standards for EV charging systems and the IEC standards.

2.1 The structure of the charging interface

The EV charging interface is divided into DC charging interface and AC charging interface according to the charging category. The structure of the AC charging interface for EVs is relatively single in China's national standards, while the structure in the IEC standards is relatively diverse, as shown in Table 1. Similarly, the DC charging interface structure is relatively single in China's national standards, while the structure in the IEC standards is relatively diverse, as shown in Table 2.

Table 1. Comparison of AC charging ports for EVs.

China national standards: GB/T20234.1-2015, GB/T20234.2-2015	IEC standards: IEC 62196-1:2014, IEC62196 -2:2016
Suitable for AC250V 10/16/31A single-phase interfaces or AC440V 16/32/63A three-phase interfaces	Structure 1: Suitable for AC250V/32A single-phase interfaces Structure 2: Suitable for AC250V/70A single-phase interfaces or AC480V/63A three-phase interfaces Structure 3: Suitable for AC250V/16、32A single- phase interfaces or

	AC480V/63A three-phase interfaces
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Table 2. Comparison of DC charging ports for EVs.

China national standards: GB/T20234.1-2015, GB/T20234.3-2015	IEC standards: IEC 62196-1:2014, IEC62196 -3:2014
Suitable for 750V/1000V 80/125/250A	Structure AA: Suitable for up to DC600V/200A Structure BB: Suitable for up to DC750V/250A Structure EE: Suitable for up to DC600V/200A Structure FF: Suitable for up to DC1000V/200A

2.2 Protection level

As for China's standards on protection level, it is only generally stated that the protection level of the power supply plug, power supply socket and vehicle socket connected to the corresponding protection device should reach IP54 respectively; when the power supply plug, power supply socket and vehicle plug are plugged together, their protection level should be at least IP55. As for IEC standards, there is no specific regulation on protection level, which is based on the self-declaration of the enterprise, and after the protection level test, all electrical accessories should be able to withstand the moisture conditions that may occur during normal use, and the specimens should be stored in a humidified box for 7 days and subjected to a moisture treatment check, followed by insulation resistance measurements and electrical strength tests as specified in IEC 62196.1, Chapter 21.

Compared to national standards, the IEC standard is stricter in that it includes a moisture control check, insulation resistance measurement and electrical strength test in addition to the protection level test.

2.3 Insulation resistance and dielectric strength

According to China's standard, insulation resistance is measured by DC500V; when $50 < U_i \leq 415$, the dielectric test voltage is 2000V; when $415 < U_i \leq 500$, the dielectric test voltage is 2500V; when $U_i > 500$, the dielectric test voltage is 3000V.

According to IEC standard, the insulation resistance is measured by DC500V when the rated voltage is less than or equal to 500V, and DC1000V when the rated voltage is greater than 500V; when the frequency dielectric test is conducted at $50 < U_i \leq 500$, the test voltage of dielectric test is 2000V; when $U_i > 500$, the test voltage of dielectric test is $2U_i + 1000$.

2.4 Breaking capability

According to Chinese standards, the number of cycles in the breaking test of the AC interface is determined by the rated current, which is 3 cycles or 1 cycle respectively.; the breaking current of the DC interface is an equivalent alternating current, and the number of cycles is 1.

According to the IEC standard, the number of cycles in the breaking test of the AC interface is determined according to the rated current, which is 50 or 20 respectively; the DC interface test is still under consideration.

In the breaking test of the AC interface, the IEC standard has more cycle times for product tests than the China's national standard, and the assessment of the product is more strict, with higher requirements for product quality; the breaking test of the DC interface, the national standard is based on the equivalent AC current processing, the IEC standard is still under consideration.

2.5 Service life (under normal operation)

According to China's standards, both DC charging interface or AC charging interface should withstand no-load live (rated voltage, no current) plugging and unplugging operation cycle of 10,000 times.

According to IEC standards, AC interfaces should withstand both live and no-load tests, the total number of operation cycles is 10,000, with different rated current ranges and different numbers of live and no-load tests; DC interfaces should withstand 10,000 no-load live plugging and unplugging operation cycles.

For AC interface, the IEC standard conducts the no-load test as well as the live-load test, which evaluates the service life of the product in the live-load operation process. China's national standard does not have an assessment of the product load test in the AC interface.

2.6 Heat resistance test

According to Chinese standards, the samples for heat resistance test are stored in a heating box at a temperature of $(100 \pm 5)^\circ\text{C}$ for 1h.

According to the IEC standard, the samples for heat resistance test are stored in a heating box at a temperature of $(110 \pm 5)^\circ\text{C}$ for 1h.

In the heat resistance test, the test temperature of the IEC standard is higher than China's national standard, and the assessment of the material of the product is stricter.

3 Construction of Comprehensive Evaluation Model for EV Charging System Standards

3.1 Construction of Comprehensive Evaluation Index System for EV Charging System Standards

Based on the analysis in Section 2, the comprehensive evaluation index system for EV charging system standards constructed in this paper is shown in Figure 1, which includes charging interfaces structure, protection level, insulation resistance and dielectric strength, breaking capability, service life (under normal operation), heat resistance test, total of 6 indicators.

Figure 1. Comprehensive evaluation index system of EV charging system standards.

3.2 Construction of a comprehensive evaluation model for EV charging system standards based on fuzzy TOPSIS

MCDM technique combined with fuzzy set theory has been extensively employed to deal with the ambiguity and uncertainty in the decision-making issues. Fuzzy TOPSIS conducts the combination of fuzzy set theory and traditional TOPSIS method, which uses triangular fuzzy number to represent the value of criteria [6]. Generally, the linguistic variables are used by the decision makers to assess the weights of criteria and the ratings of alternatives in fuzzy TOPSIS method. For fuzzy TOPSIS method, the entry in the decision matrix is represented by triangular fuzzy number. This kind of representation may be a better way to characterize the practical issues under fuzzy environment. The specific steps of fuzzy TOPSIS method are as below [7].

Step 1: Calculate the aggregate fuzzy linguistic ratings for criteria performance of alternatives.

Step 2: Determine the aggregated fuzzy weights of criteria.

Step 3: Build the initial fuzzy decision matrix.

Step 4: Normalize the initial fuzzy decision matrix.

Step 5: Construct the weighted normalized fuzzy decision matrix.

Step 6: Determine the fuzzy positive and negative ideal solution.

Step 7: Calculate the distance of each alternative from fuzzy positive and negative ideal solution.

Step 8: Compute the closeness coefficient of each alternative.

Step 9: Rank the alternatives.

The detailed calculation method and equations can refer to Ref. [7].

4 Empirical research on comprehensive evaluation of EV charging system standards.

In the process of comprehensive evaluation of EV charging system standards, relevant personnel from power grid companies, industry standard customization

experts, and professors from professional colleges are selected to form an evaluation expert group to conduct language evaluation of various indicators of China's and IEC EV charging system standards. The specific process is as follows.

The evaluation expert group conducted language evaluation on the 6 evaluation indicators of China's and IEC EV charging system standards. The results are shown in Table 3.

Table 3. Results of standard evaluation index language for EV charging system based on evaluation expert group.

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆
China	G	L	G	H	G	G
IEC	H	H	G	L	H	H

According to Table 3, the triangular fuzzy number of the standard evaluation index scores of China's and IEC EV charging system can be obtained, and the comprehensive fuzzy language level value of the standard evaluation index scores of China's and IEC EV charging system can be calculated,

$$A = \begin{bmatrix} \begin{matrix} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{matrix} \\ \begin{pmatrix} 0.3 & 0.5 & 0.7 \\ 0.6 & 0.8 & 1 \end{pmatrix} & \begin{pmatrix} 0 & 0.2 & 0.4 \\ 0.6 & 0.8 & 1 \end{pmatrix} & \begin{pmatrix} 0.3 & 0.5 & 0.7 \\ 0.3 & 0.5 & 0.7 \end{pmatrix} & \begin{pmatrix} 0.6 & 0.8 & 1 \\ 0 & 0.2 & 0.4 \end{pmatrix} & \begin{pmatrix} 0.3 & 0.5 & 0.7 \\ 0.6 & 0.8 & 1 \end{pmatrix} & \begin{pmatrix} 0.3 & 0.5 & 0.7 \\ 0.6 & 0.8 & 1 \end{pmatrix} \end{bmatrix}$$

Then, the comprehensive fuzzy language level values of the standard evaluation indicators for the six EV charging systems can be calculated, namely:

$$\tilde{s} = \begin{bmatrix} \begin{matrix} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{matrix} \\ \begin{pmatrix} 0.2 & 0.5 & 0.8 \\ 0.5 & 0.7 & 1 \end{pmatrix} & \begin{pmatrix} 0.5 & 0.7 & 1 \\ 0 & 0.3 & 0.5 \end{pmatrix} & \begin{pmatrix} 0 & 0.3 & 0.5 \\ 0.5 & 0.7 & 1 \end{pmatrix} & \begin{pmatrix} 0.5 & 0.7 & 1 \\ 0.2 & 0.5 & 0.8 \end{pmatrix} & \begin{pmatrix} 0.2 & 0.5 & 0.8 \\ 0 & 0.3 & 0.5 \end{pmatrix} \end{bmatrix}$$

Among the six standard evaluation indicators for EV charging systems, all are very large indicators. Based on this, a standardized fuzzy decision matrix can be obtained, and then the weighted standardized fuzzy decision matrix can be obtained as:

$$C = \begin{bmatrix} \begin{matrix} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \end{matrix} \\ \begin{pmatrix} 0.06 & 0.25 & 0.56 \\ 0.12 & 0.4 & 0.8 \end{pmatrix} & \begin{pmatrix} 0 & 0.14 & 0.4 \\ 0.3 & 0.56 & 1 \end{pmatrix} & \begin{pmatrix} 0 & 0.21 & 0.5 \\ 0 & 0.21 & 0.5 \end{pmatrix} & \begin{pmatrix} 0.3 & 0.56 & 1 \\ 0 & 0.14 & 0.4 \end{pmatrix} & \begin{pmatrix} 0.06 & 0.25 & 0.56 \\ 0.12 & 0.4 & 0.8 \end{pmatrix} & \begin{pmatrix} 0 & 0.15 & 0.35 \\ 0 & 0.24 & 0.5 \end{pmatrix} \end{bmatrix}$$

Then, the fuzzy positive and negative ideal solutions can be obtained, and we can obtain China's and IEC EV charging system standards and fuzzy positive ideal solutions and fuzzy negative ideals and the closeness of China's and IEC EV charging system standards is 0.466034 and 0.533966, respectively.

Finally, based on the above calculation, the closeness value represents the comprehensive evaluation level of the EV charging system standards. The higher the value, the more comprehensive evaluation results of the EV charging system standards. it is good. From the calculation result, it can be seen that the comprehensive evaluation result of the IEC EV charging system standard is relatively high, and there is still a certain gap between China's EV charging system standard and the IEC's standard.

5 Conclusion

Currently, China's EVs are developing rapidly. In recent years, China has paid more and more attention and attach more and more importance to the international standardization of EV charging systems. This article compares and analyzes China's EV charging system standards and the international IEC EV charging system standards, mainly including the charging interface structure, protection level, insulation resistance and

dielectric strength, breaking capability, service life and heat resistance test. On the other hand, based on the fuzzy TOPSIS method, a comprehensive evaluation model of EV charging system standards is constructed, and an empirical comparison and analysis of China and IEC EV charging system standards are carried out. The results show that although China's EV charging system standards are stronger than the IEC standards in some aspects, there is still a certain gap with the IEC standards as a whole, especially in terms of protection level and heat resistance test. The harmonization of national standards and international standards is conducive to the universal interchange of products, and is of great significance for products to go abroad and enter the international market. Therefore, for the development of China's future EV charging system standards, it is necessary to connect with IEC international standards, improve China's standard level, further promote the international standardization of China's charging scheme, and enhance China's voice and influence in the international EV field.

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References

1. Dong Xiaohong, Mu Yunfei, Jia Hongjie, et al. Planning of Fast EV Charging Stations on a Round Freeway[J]. IEEE Transactions on Sustainable Energy, 2016,7(4):1-10.
2. Wang Xiwen. International development trend of electric vehicle charging standard[J]. Power Demand Side Management, 2013, 15(5): 60-62.
3. Wang Qianqian, Li Haidong, Wang Yiqun. Analysis and research on the key indicators of electric vehicle's conduction charge coupler at home and abroad[J]. Standard Science, 2013(12): 80-83.
4. Zhen Zijian, Meng Xiangfeng. State of the art and research of the charging coupler standards in China and abroad[J]. Chinese Journal of Automotive Engineering, 2012, 2(1): 1-7.
5. Li Hexin, Du Hongliang, Wang Yanbo, et al. Analysis of the difference between the national standard and IEC standard of electric vehicle charging interface[J]. China Standardization, 2018(10): 13-14.
6. Zhao H, Guo S. Selecting Green Supplier of Thermal Power Equipment by Using a Hybrid MCDM Method for Sustainability[J]. Sustainability. 2014, 6:217-35.
7. Zadeh LA. FUZZY SETS[J]. Information and Control. 1965, 8:338-53.
8. Guo S, Zhao H. Optimal site selection of electric vehicle charging station by using fuzzy TOPSIS based on sustainability perspective[J]. Applied Energy, 158: 390-402.