Theory and Practice of Science and Technology
2025, VOL. 6, NO. 4, 104-108
DOI: 10.47297/taposatWSP2633-456917.20250604

Site selection analysis of DC Converter Stations based on F-AHP method

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ABSTRACT

In order to solve the problem of DC converter stations site selection, based on the in-depth analysis of multiple influencing factors, the fuzzy hierarchical analysis method is used for decision-making evaluation, so as to construct a DC converter station site selection evaluation index system and obtain the optimal solution for site selection. Then, a case analysis is conducted on the site selection of the Fujian-Guangdong interconnected 500kV back-to-back DC converter station. The analysis results show that the construction of a new Fujian-Guangdong interconnected converter station at the Shiqin site is consistent with the final planning scheme, which verifies the feasibility and accuracy of the converter station site selection evaluation index system in this study.

KEYWORDS

Fujian-Guangdong Power interconnection; Converter station; Site selection; Fuzzy Analytic Hierarchy Process; index

DC converter stations are key hub facilities that convert AC to DC or DC to AC, and are usually used in ultra-long-distance, large-capacity transmission systems. With the continuous growth of electricity demand and the increasing complexity of power grids, DC converter stations play an indispensable role in power systems. Therefore, the rationality of the site selection of DC converter stations can reduce construction costs and improve the anti-interference ability of the power grid[1], which has far-reaching economic and social significance.

This study will conduct a comprehensive analysis of the factors affecting the site selection of DC converter stations, construct a quantitative, convenient and operational evaluation system, and use the actual case of the Fujian-Guangdong interconnected 500kV back-to-back DC converter station, a key project of China's "14th Five-Year Plan", to verify the constructed evaluation system, thereby enriching the theoretical support for the planning and site selection of converter stations.

1 Factors affecting site selection

The evaluation and selection of substation locations, including converter stations, is an important strategic decision-making issue faced by the public and private sectors[2], and its stakeholders mainly include power grids, local governments and the public. The current situation and requirements of regional economic and social development, resources and environment, infrastructure, etc. should be comprehensively considered, and the principles of scientificity, rationality, convenience and sustainable development should be followed. According to the relevant national power development plan, the converter station site should be reasonably set to ensure the smooth implementation of the project and maximize the social, economic and environmental benefits of the project.

1.1 Site factors

When selecting a site for a converter station, environmental impact is a factor that cannot be ignored. The difficulty of land use is directly related to the speed of project advancement and the cost of land use. If the site involves complex land structures or environmental protection areas at different levels, the utilization process may become very difficult. In addition, the site environment must meet the specific requirements of the relevant national standards for converter station site selection to avoid obstacles in project approval and future operation.

1.2 Pre-construction cost factors

The difference in construction investment brought about by the standardized construction of converter stations mainly comes from the initial construction costs of different site selections. The transportation conditions, engineering geological conditions, and construction conditions of the power station site directly affect its construction costs[3]. Good transportation conditions, engineering geological conditions, and construction conditions can reduce transportation costs and reduce potential construction risks. In addition, the construction cost of the backup external power supply line needs to be considered.

1.3 Local status factors

The local current situation is an important condition that affects the selection of site. The site needs to be coordinated with the surrounding settlements and local infrastructure conditions to avoid adverse effects on the lives of local residents and station operations, while making use of existing infrastructure as much as possible to save construction and operation costs.

1.4 Planning factors

The site selection of DC converter stations must fully consider the requirements of the overall national land space planning. With the implementation of China's new round of national land space planning, the site selection and layout of station facilities must comply with the control and guidelines of national land space planning[4]. In addition, the land use nature of the converter station must also comply with the provisions of the relevant planning to ensure that it does not affect the construction of other key development projects or public facilities.

1.5 Residential factors

Public acceptance plays a key role in the smooth progress of the project[5]. The construction and operation of the converter station may have an impact on the daily lives of local residents. Therefore, the site should be as far away from residential areas as possible to reduce interference to residents from electromagnetic radiation, equipment noise, etc. In addition, the project site selection should also consider the impact on local transportation.

1.6 Environmental factors

The site selection of the converter station must also fully consider the impact on the natural environment. The power station construction area should be kept at a certain distance from the existing waters and avoid ecologically sensitive areas such as environmental protection areas to avoid damage to the local ecosystem[6]. Secondly, the converter station will generate certain electromagnetic radiation and equipment noise. When selecting the site, it is necessary to consider the potential impact on surrounding residents and animals and plants. Finally, the site selection must also comply with the relevant requirements of the country's "three zones and three lines" to ensure the project's environmental compliance.

2 Comprehensive evaluation method for converter stations site selection

2.1 Construction of evaluation index system

Based on the analysis of factors affecting site selection in the previous article, a converter station site selection evaluation index system is constructed, as shown in Table 1.

Table 1 DC converter station site selection evaluation index system

Comprehensive evaluation of DC converter stations site selection (A)	Site factors(B1)	Difficulty of land acquisition and relocation(C1)
		Compliance with site environment standards (C2)
	Pre-construction cost factors(B2)	Traffic conditions for transporting large equipment (C3)
		Backup external power supply construction cost (C4)
		Land preparation costs for the proposed site (C5)
	Local status factors(B3)	Degree of coordination with surrounding villages (C6)
		Degree of coordination with local municipal infrastructure configuration (C7)
		Coordination degree with local fire protection supporting conditions (C8)
	Planning factors(B4)	Coordination degree with the overall planning of each level (C9)
		Coordination degree with land use characteristics (C10)
		Coordination degree with village planning (C11)
	Residential factors(B5)	Pressure on social stability (C12)
		Regional relationship with settlements (C13)
		Impact on the travel of surrounding residents (C14)
	Environmental factors(B6)	Relationship with local protected areas (C15)
		Electromagnetic environment impact (C16)
		Equipment noise impact (C17)
		Impact of the "Three Regions and Three Lines" (C18)

Influencing factors can be divided into qualitative description and quantitative data. Qualitative description refers to those characteristics that are difficult to express with numerical values, which usually need to be described in natural language, such as the degree of coordination of various aspects and the impact of the ecological environment.

Quantitative data, on the other hand, are factors that can be expressed with specific numerical values, such as large-scale transportation costs, initial construction costs, and land acquisition and demolition costs, etc., obtained through data collection, statistical analysis or calculation.

2.2 Determining indicator weights

After establishing the site selection evaluation index system, the complex decision-making is structured into a hierarchical structure from the overall to the hierarchical level, which is decomposed into various "standards", "sub-standards", etc., down to the lowest level [7]. Specifically, in order to determine the factor weight of Bi relative to A or Ci relative to Bi, it is necessary to make a pairwise comparison of the importance of Bi relative to A or Ci relative to Bi, so as to form an i×i or j×j judgment matrix, and solve it to obtain the weight of each factor relative to the previous level. This study used an offline questionnaire and invited 25 engineers and university teachers engaged in the fields of land space planning and power planning to participate in the questionnaire survey. At the same time, we listened to their opinions on this study and their evaluation of the index system, and adjusted and revised the evaluation system in a timely manner according to their opinions. Through data analysis, calculation and consistency test, the indicator weight values of the indicator layer C1-C18 relative to the criterion layer B1-B6 were obtained.

The details are as follows:

W (B1)= [0.5385, 0.4615]

W (B2)= [0.3885, 0.3737, 0.2378]

W (B3)= [0.3923, 0.3269, 0.2808]

W (B4)= [0.3352, 0.3318, 0.3330]

W (B5)= [0.3054, 0.3687, 0.3259]

W (B6)= [0.2479, 0.2375, 0.2425, 0.2721]

In the same way, through software calculation and consistency check, the indicator weight values of the criterion layer B1-B6 relative to the target layer A can be obtained as follows:

W (A)= [0.2584, 0.2189, 0.1697, 0.1125, 0.1392, 0.1013]

After obtaining the weight of the indicator layer relative to the criterion layer and the weight of the criterion layer relative to the target layer, the evaluation results of the indicator layer and the criterion layer can be superimposed, and then the target layer can be superimposed to obtain the AHP evaluation result [8], that is, the weight of the indicator layer C1-C18 relative to the target layer A, as shown in Table 2. In this way, a comprehensive evaluation conclusion based on the fuzzy hierarchical analysis method can be obtained.

Table 2 :Weight analysis table of converter station site selection model criteria layer

Indicator-level factors(C)	Criteria-level factors(B)						Total weight
	B1 (0.2584)	B2 (0.2189)	B3 (0.1697)	B4 (0.1125)	B5 (0.1392)	B6 (0.1013)	
C1	0.5385						0.1391
C2	0.4615						0.1193
C3		0.3885					0.0850
C4		0.3737					0.0818
C5		0.2378					0.0521
C6			0.3923				0.0666
C7			0.3269				0.0555
C8			0.2808				0.0477
C9				0.3352			0.0377
C10				0.3318			0.0373
C11				0.3330			0.0375
C12					0.3054		0.0425
C13					0.3687		0.0513
C14					0.3259		0.0454
C15						0.2479	0.0251
C16						0.2375	0.0241
C17						0.2425	0.0246
C18						0.2721	0.0276

2.3 Comprehensive evaluation steps for converter station site selection

On the basis of completing the establishment of a comprehensive evaluation system for DC converter station site selection, the comprehensive evaluation steps for site selection of specific projects are as follows:

(1) Detailed analysis of the current status of local economic, social and power grid development, combined with the local land and space master plan, to analyze the planning and construction background of the proposed converter station site;

(2) Based on the local land space master plan at all levels, regional power grid planning and the planned converter station projects, a specific comparison plan is proposed;

(3) Based on the initial construction costs of each proposed site, the coordination degree of each sub-item, technical feasibility, environmental impact and other aspects, a detailed comparative analysis of the advantages and disadvantages is carried out, and a sufficient number of experts in the power and planning industry are invited to give expert scores on 18 key indicators. The comprehensive scoring results are then substituted into the above table. After weighted average calculation, the final evaluation score of each comparison plan can be obtained.

3 Case Study: Site Selection for Converter Stations in Fujian-Guangdong Interconnection

The Fujian Guangdong Interconnection Project is a key power transmission and transformation project in the national ' 13th Five Year ' development plan[9].

The converter station for the Fujian-Guangdong interconnection adopts a conventional DC solution, with a capacity of 2000MW in the initial and final phases, and a DC side voltage of ±100kV. Considering that this interconnection project is mainly positioned to complement each other, serve as a backup for each other, and provide emergency support, the voltage level is determined to be 500kV based on the actual power grid conditions of Fujian and Guangdong provinces. The project can solve the problem of weak 500 kV power grids in southern Fujian and eastern Guangdong, and at the same time ensure the safe transmission of power generated by the Zhangzhou Nuclear Power Plant in Lieyu Town, Yunxiao County [10].

Combined with the relevant superior plans, the construction unit organized the local government, relevant scientific research units and institutions to conduct multiple on-site surveys on the site selection of the 500kV back-to-back DC converter station for the Fujian-Guangdong interconnection, and after the feasibility demonstration of the site selection planning preparation unit and the planning department, among the 9 proposed sites located between the Donglin Substation and the Jiaying Substation, the two final site selection plans of Shiqin Village and Jianhe Village in Yunxiao County were determined.

Option 1: Shiqin Station is located on a slope about 340m west of Shiqin Village, Mapu Township, Yunxiao County, Zhangzhou. It is about 700m south of Mapu Township, about 19km from Yunxiao County, about 56km north of Zhangzhou City, and close to County Road X520 on the west. The station is close to Mapu Township, close to the water plant, planned sewage treatment plant in the town, fire station and other municipal facilities, and is far from the straight route of the 500kV overhead line, which increases the installation distance of the 500kV overhead line.

Option 2: Jianhe Station is located near the west side of Jianhe Village, Mapu Township, Yunxiao County. The station is about 6km south of Mapu Township, about 24km from Yunxiao County, and about 50km north of Zhangzhou City. The current land acquisition and relocation investment is relatively small, and it is located on the straight route of the 500kV overhead line.

The current elevation difference of the land is large, far away from Mapu Township, the investment in the construction of supporting municipal facilities is large, and the land occupies part of the current X520 County Road.

Based on the detailed analysis and comparison of the advantages and disadvantages and parameter characteristics of the alternatives, this study invited 31 experts from different fields including electricity, natural resources, agriculture and forestry, transportation, etc. to conduct a questionnaire survey. Each expert scored the two alternatives and evaluated the opinions and plans of this study. In this way, the comprehensive scores of 31 experts for 18 indicators were collected, and the final scores of the two alternatives were obtained. Assuming that the score of each option is recorded as Z, the score calculation formula of the alternative is as follows:

$$Z(i) = \sum_{j=1}^{18} C_j(i) \cdot W(C_j)$$

Wherein: i is 1 or 2 according to the proposed site selection scheme; Z(i) is the comprehensive score of the evaluation index system of scheme i; Cj (i) is the comprehensive score of the jth influencing factor of scheme i; W(Cj) is the comprehensive weight of the jth influencing factor of the converter station site selection evaluation index system.

Calculation shows that Z(1)=7.54, Z(2)=7.16.

The results show that the recommended plan of this evaluation is consistent with the site selection approved by the municipal and county natural resources authorities after multiple rounds of planning and site selection demonstrations, indicating that the comprehensive evaluation index system and evaluation method for the site selection of DC converter stations in this study have high credibility and accuracy.

4 Conclusion and Prospect

Based on the fuzzy analytic hierarchy process, this study constructed a comprehensive evaluation index system for the site selection of DC converter stations. By analyzing factors such as environmental impact, construction cost, local status, urban and rural planning, public impact and ecological impact, a detailed hierarchical evaluation model was established. The case analysis results show that the site plan recommended by the comprehensive evaluation index system is consistent with the actual site selection that has been scientifically demonstrated by experts, scholars and business departments at multiple levels, which effectively verifies the high credibility and accuracy of the evaluation method and index system.

This study not only provides systematic decision support for the site selection of DC converter stations, but also provides a powerful reference framework for site selection analysis of similar large-scale engineering projects. Future work can further optimize the evaluation indicators and methods based on existing research to cope with more complex site selection challenges.

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