Quantitative Study on Carbon Emission Reduction of UHV AC Engineering Equipment Transportation

Shuo Wang[1](✉), Weiwei Li[1], Xin Qie[2], Huijuan Huo[1], Yijiang Liu[1], Dan Xu[1], and Litong Dong[1]

[1] State Grid Economic and Technological Research Institute Co., Ltd, Beijing 102211, China
hdsylyd@163.com
[2] State Grid Corporation of China, Beijing 100031, China

Abstract. The construction of UHV AC projects has significant advantages in improving the clean energy consumption capacity and optimizing the large-scale allocation of energy resources. At present, the carbon emission reduction benefits of UHV AC projects have not been quantitatively studied, and equipment transportation is an important part of UHV AC project construction. Based on this, the paper determines the boundary of carbon emission accounting system in the equipment transportation stage, clarifies the key factors of carbon emission reduction in this stage, and proposes carbon emission accounting methods. Through the analysis of an actual project, the results show that the equipment transportation link can reduce carbon emissions and improve the carbon reduction benefits of ultra-high voltage AC projects by optimizing the transportation path and mode.

Keywords: UHV AC project · Equipment transportation · Transportation distance · Carbon emissions

1 Introduction

In September 2020, China pledged to increase its national independent contribution and adopt more forceful policies and measures, aiming to reach its peak carbon dioxide emissions by 2030 and striving to achieve carbon neutralization by 2060. The electric power industry is the main source of carbon emission in China and the key field of carbon emission reduction [1]. The power grid undertakes the responsibility of serving the large-scale development and utilization of clean energy such as new energy, is an important carrier connecting energy production and consumption, and plays a leading role in realizing clean and low-carbon transformation of energy and power [2]. Under the requirements of the dual-carbon target, SGCC earnestly implements the national energy security strategy of “four revolutions and one cooperation”, makes every effort to promote the rapid development of clean energy, speeds up the construction of a diversified and clean energy supply system, and promotes the clean, low-carbon, safe and efficient use of energy.

J. Yen et al. (Eds.): ICBIS 2023, AHCS 14, pp. 564–571, 2023.
https://doi.org/10.2991/978-94-6463-198-2_58

As new energy becomes the main part of the power structure, the power side presents instability and dispersion, and the anchor point of the power system will be transferred from the power side to the power grid side. Under this situation, the support function of UHV to the power grid will be greatly enhanced. The construction and development of UHV project is an important part of the construction of new power system and also an important link to realize the transformation and upgrading of traditional power grid to energy Internet [3]. The construction of UHV project will play a greater role in optimizing grid structure and promoting the absorption of clean energy resources. Energy resources and load demand in China are distributed in reverse direction. Clean energy is mostly distributed in the "three north" and southwest areas, far from the East load center. UHV power grid, with comprehensive advantages of long distance, large capacity, low loss and less land occupation, is the most advanced transmission technology in the world [4]. Under the goal of "carbon peak and carbon neutralization", the construction of UHV project will play a significant role in promoting the balance of supply and demand of energy and power in China, promoting the large-scale optimal allocation of clean energy resources, improving the absorbability of clean energy, and realizing low-carbon development in load center areas [5–7].

Due to the hidden dangers of AC engineering in system stability, the situation of strong, direct and weak AC has gradually formed in the construction and development of UHV engineering, which makes the relatively complete network of AC UHV lines still not formed so far and can not provide strong support for DC lines [8]. In the future, only by improving the backbone network of AC projects can we ensure the safe and smooth operation of UHV power grid in China. Based on this, this paper mainly focuses on the carbon reduction benefits of UHV AC project, analyses the emission reduction potential of equipment transportation, defines the carbon emission accounting boundary at this stage, and proposes a carbon emission accounting model. Finally, an example of a typical project is used to verify the potential of emission reduction during equipment transportation and put forward relevant suggestions.

2 Analysis of Carbon Emission Reduction in Equipment Transport Phase

2.1 Carbon Emission Accounting System Boundary for Equipment Transportation Phase

Carbon emission accounting of UHV AC engineering equipment during transportation phase mainly includes carbon emission generated by equipment material transportation during this phase. The main sources of emissions are direct carbon emissions from burning fuel in transportation vehicles or indirect carbon emissions from using electric energy [9]. Carbon emission during transportation is mainly caused by large equipment such as main transformer, high-voltage reactor and various types of wire with large total weight.

2.2 Carbon Emission Accounting Method

Generally speaking, the carbon emission of transportation can be determined by the weight of equipment, transportation distance and carbon emission factor [10]. The specific calculation process is shown in formula (1).

$$C_{tr} = MDT \tag{1}$$

Among them, C_{tr} refers to the carbon emission during transportation, M refers to the total weight of the transported goods, D refers to the transportation distance, and T refers to the carbon emission factor of the transportation distance per unit weight, which is determined according to the transportation mode. The weight of the transported goods determines the transportation capacity demand in the transportation process, and the transportation distance is the most representative energy consumption indicator in the driving process of the transport vehicle.

The above three multipliers are often used to reduce the carbon emissions in transportation. As the equipment weight of UHV AC power grid construction project is closely related to the equipment performance, the equipment transportation distance and carbon emission factor are the key to emission reduction in the transportation link of UHV AC power grid construction project.

The transportation distance is related to the supply chain architecture and the transportation routes. The supply chain architecture mainly includes the optional transportation modes of the upstream equipment and materials delivery place, and the transportation distance between the upstream equipment and materials and the project construction site. The transportation route includes not only the total transportation distance, but also the mileage proportion of different transportation modes in the whole transportation process.

The carbon emission factors vary greatly due to different transportation modes. In the truck transport mode, under the same fuel condition, the higher the load capacity and the larger the model, the lower the carbon emission intensity of trucks. However, in the comparison between gasoline trucks and diesel trucks, the carbon emission intensity of light gasoline trucks is higher than that of light diesel trucks, and the carbon emission intensity of gasoline trucks of other models is lower.

3 Calculation Model of Carbon Emission Reduction in Equipment Transportation Stage

3.1 Transmission Line Engineering

UHV AC project line engineering mainly involves the transportation of basic equipment materials such as wire materials. Generally speaking, carbon emission accounting for this part can refer to GB/T51366-2019 Standard for Calculating Carbon Emissions in Buildings issued by the Ministry of Housing and Construction in 2019, and use carbon emission factors of different modes of transportation in this standard for carbon emission accounting. The specific calculation method is shown in formula (2).

$$C_{ys} = \sum_{i=1}^{n} M_i D_i T_i \tag{2}$$

Among them, C_{ys} represents the carbon emission (kg CO_2e), M_i represents the total weight (t), D_i represents the average transportation distance (km) of the material, and T_i

represents the carbon emission factor (kg CO_2e/(t * km) per unit weight transportation distance of the material under the mode of transportation of the material. Reference to GB/T 51366-2019 Building Carbon Emission Calculation Standard.

3.2 Substation Engineering

Transportation phase of UHV AC power plant is mainly composed of large pieces. For a certain phase, the same means of transportation are often used and only a few pieces of large pieces of equipment are transported one ship or one vehicle at a time. The difference of total load per time is large, but the energy consumption data per kilometer is similar. Therefore, the above basic transportation carbon emission accounting methods are amended for large-scale equipment transportation and mainly in the form of equipment transportation. As shown in formula (3).

$$C_{ys} = \sum_{k=1}^{n} n_k D_k v_k \rho_k ET_k \tag{3}$$

Among them, C_{ys} represents the carbon emission (kg CO2 e) during equipment transportation, n_k represents the total number of transportation times for type k equipment transportation, D_k represents the single transportation distance (km) for type k equipment transportation, v_k represents the fuel consumption (L/km) per kilometer for type k equipment transportation, and ρ_k represents the fuel density (kg/L) for type J equipment transportation. ET_k represents the carbon emission factor per unit weight of energy consumption (kg CO2e/kg) for the type k equipment transportation.

4 Example Analysis

4.1 Scenario Setting

Taking an engineering equipment transportation as an example, the carbon emission measurement of UHV AC engineering equipment transportation is carried out. Data on equipment transportation available at present are shown in Table 1. The main equipment includes 6 main transformers (single weight 397 t) and 6 high voltage reactors (single weight 180 t). The self-weight, long transportation distance, high requirement on transport vehicles, high requirement on the strength and pressure level of the transportation path itself, and large carbon emissions during transportation process of these large equipment. Relevant data of transportation mode are shown in Table 1.

According to the transportation path planning, two transportation schemes are set:

Scheme I: 1447 km of water transportation, including 1350 km of sea transportation, 97 km of inland river transportation and 294 km of road transportation.

Scheme II: 1617 km of water transportation, including 1520 km of sea transportation, 97 km of inland river transportation and 36 km of road transportation.

All large equipment shall be transported by waterway and highway. For the marine transportation, 1500 ton general cargo ships are mainly used, and the energy consumption for 100 km transportation is about 50 L diesel oil. A single ship can complete the

Table 1. Equipment Transportation Mode

Mode	Means of transport	Energy consumption	Energy consumption per kilometer (L)
Waterway transportation	1500t general cargo ship (sea transportation) + 700t front cockpit deep cabin barge (inland river)	Diesel oil	50
Road transport	Tractor + 3 longitudinal 14 axis hydraulic flat car	Diesel oil	140

transportation of 3 main transformers or 6 high-voltage reactors in this section, and it requires at least 3 ships to complete all heavy cargo transportation. For inland waterway transportation, 700 ton forward cockpit deep cabin barge is mainly used, and the energy consumption for 100 km transportation is about 50 L diesel oil. For equipment safety reasons, under the condition that different types of equipment are not loaded together, a single ship can complete the transportation of one main transformer or three high-voltage reactors in this section, and it requires at least eight ships to complete all large cargo transportation. For road transportation, "tractor + 3 longitudinal 14 axis hydraulic flat car" is mainly used, with a check load of nearly 400 tons, which can ensure the safety and stability of the transportation of mountain roads, bridges and culverts. The energy consumption per kilometer of transportation is about 140 L diesel. A single vehicle can complete the transportation of one main transformer or two high-voltage reactors in this section, and it requires at least 9 vehicles to complete the transportation of all bulky goods.

4.2 Carbon Emission Reduction Accounting

The carbon emissions of transportation schemes I and II of the Project are calculated by adopting diesel density of 0.84 kg/L and carbon emission factor of 3.10 kg CO2e/kg per unit diesel consumption. The calculation results are shown in Table 2.

Table 2. Carbon Emission of UHV AC Project in Transportation Stage

	Transportation form	D_k	v_k	ρ_k	ET_k	C_{ys}
Scheme I	Sea transport	1350	50	0.84	3.1	527.3
	Inland waterway transportation	97	50	0.84	3.1	101.0
	Road transport	294	140	0.84	3.1	964.6
Scheme II	Sea transport	1320	50	0.84	3.1	515.6
	Inland waterway transportation	97	50	0.84	3.1	101.0
	Road transport	26	140	0.84	3.1	85.3

In this UHV AC project, due to the different road transportation distance between Scheme I and Scheme II, the carbon emission of Scheme I is 891 t CO2e higher than that of Scheme II. Generally speaking, when the deadweight of large equipment is too large, in order to ensure the stability and safety of transportation, it is necessary to reinforce and transform the road sections, bridges, culverts, etc. that will cause additional carbon emissions.

5 Conclusion and Suggestions

This paper defines the carbon emission accounting boundary in the transportation stage of engineering equipment, defines the key factors of carbon emission reduction in the transportation stage of equipment, starts with the weight of equipment, transportation distance and carbon emission factors of transportation tools, and conducts an actual example analysis. The results show that the carbon emission can be reduced and the carbon reduction benefits of ultra-high voltage AC projects can be improved by optimizing the transportation path and transportation mode in the equipment transportation link. In the subsequent ultra-high voltage AC project construction, referring to the carbon emission calculation model of the transport link established in this paper, the carbon emission reduction of equipment transport can be started from the following three aspects.

First, priority should be given to equipment procurement in neighboring cities, railway developed cities or port cities. The carbon emissions in the transport phase of equipment are proportional to the transport distance. Equipment procurement from the city or neighboring cities can fundamentally reduce the total carbon emissions in the transport phase. If it cannot be met, cities with developed railway or waterway transportation should be selected as far as possible for equipment procurement. Generally speaking, no less than 50% of railway or waterway transportation is used throughout the transportation, and the total carbon emissions can be reduced by more than 30%.

Second, transport modes with low carbon emission factors, such as railway transport and waterway transport, should be preferred. Due to different carbon emission factors, compared with truck transportation, railway or waterway transportation can reduce carbon emissions by 33%–97% in the same transportation mileage. In truck transportation, diesel trucks with a load capacity of less than 2 tons are better, which can reduce carbon emissions by about 14% compared with gasoline trucks with the same load capacity; When the load capacity is 8–18 t, the gasoline truck is better, and compared with the diesel truck with the same load capacity, the carbon emissions can be reduced by 19%–36%; When the load capacity is more than 18 tons, the diesel truck is better. Compared with the heavy gasoline truck that has completed the task of transporting goods with the same weight, the carbon emission is reduced by 25%–45%.

Therefore, the construction projects in coastal areas can adopt the method of long distance sea transportation combined with short distance land transportation to complete the equipment transportation. In the inland area, the construction project can give priority to railway transportation under the premise of cost control. In the necessary truck transport stage, heavy diesel trucks with higher load capacity shall be used as the main transport force for the project blocks requiring super large equipment (more than 18 tons), and light diesel trucks shall be used as far as possible for the project blocks with small equipment demand.

Third, the transportation system should adopt grid management. As the construction sites of ultra-high voltage AC power grid construction projects are often scattered, and the project radiation range is large, during the equipment transportation process, it is necessary to ensure the efficient linkage between various regions, and it is more feasible to obtain the transportation scheme with the best economic cost and carbon emission reduction effect through network management. Firstly, calculate the mileage distance between various equipment supply places and each main construction section, give priority to the transportation mode with high load capacity and low emission, and transport the equipment to each main construction section with the optimal transportation plan. Then, considering the geographical conditions, road conditions, local transportation economic costs and other factors of each construction section, determine the radiation range of the main construction section, form a construction network with scattered secondary construction sections and main construction sections, and then select the transportation mode with low carbon emissions and low economic costs according to the equipment requirements of the secondary construction sections.

References

1. Yang F, Zhang JJ. Current situation and prospect of low carbon development in China's power industry under the target of carbon peaking and carbon neutralization [J] Environmental Protection, 2021, 49 (17): 6.
2. Rao H. The digital grid promotes the construction of a new power system with new energy as the main body [J] Power Equipment Management, 2021 (8): 2.
3. Ma ZM. Build a good UHV project to build a foundation for the global energy Internet [J] North China Electric Power, 2015 (6): 1.
4. Zhao HR, Zhao YH, Wang LY, et al. Comprehensive benefit evaluation of UHV transmission project based on Bayesian optimal worst and improved matter-element extension [J] China Power, 2022, 55 (6): 11.
5. Jia BY, Li W. UHV power grid can rapidly improve the level of clean energy consumption [J] Digital users, 2017, 023 (042): 36–37.
6. Zhou YX, Chen JN, Zhang L, et al. Development Opportunities of UHV Transmission Technology under the Background of "Double Carbon" and "New Infrastructure" [J] High Voltage Technology, 2021, 47 (7): 13.
7. Zhang LP. Analysis of Factors Affecting the Operation of UHV Power Grid and Solutions [J] Low Carbon World, 2017 (12): 2.
8. Luo YY, Li ZH, Zhang C, et al. Protection scheme design of multi UHV AC/DC strong coupling large receiving end power grid system in North China [J] Power System Automation, 2018, 042 (022): 11–18, 68.
9. Zhang Zm, Li S, Xu XQ. Supply chain contract coordination considering carbon emissions during product transportation [J] Computer Engineering and Application, 2022, 58 (13): 265–271.
10. Wang JL, Hu JK. Optimization of liner transport network considering carbon emissions [J] Logistics Engineering and Management, 2017, 39 (12):