Research on wind and solar energy transmission economic of Asia and Europe under Northern-hemisphere energy connection

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Abstract. Relying on the northern-hemisphere energy connection, considering the energy implementation of Asia and Europe, carrying out clean energy alternative is mainly to use the clean energy to take place of fossil energy. Under the green development scenario, this research gives the northern-hemisphere energy interconnection development model, makes the Arctic as the connection points, gives the Northern hemisphere interconnection model unite the whole world energy. This research also identifies the factors effecting the transmission changes cost, including generation cost, transmission cost and landing cost. And estimate these two continents cost benefit, its economic and variable power-jointed scheme cost competitiveness. It showed that the trans-continent mode had better benefit, and can solve the pollution and energy restriction.

1. Introduction
Energy is an important affection to the development of human civilization [1]. The development of world energy has experienced changes from high to low carbon, from low to high efficiency, from partial equilibrium to large scale configuration [2].

Global energy supply is constrained by resource reserves and rising supply costs. To the amount, fossil energy reserves are limited, non-renewable, large-scale development and utilization will lead to depletion of resources. To the layout, the world's energy resources and consumption are reverse distribution; energy exploitation is centralizing to a few countries [3, 4].

The supply costs of fossil and clean energy is showing a "one rising and one dropping". With the coal, oil, natural gas wide exploration, the marginal cost of fossil energy will be gradually improved. And it will increase the energy cost, while the clean energy cost is gradually declining, but now it is at high level. With the rapid development of clean energy technology, the cost will decrease. So we really need to exploit the rich energy areas, and transport the energy to the developed areas short of energy. Connect the northern hemisphere continents and balance the supply and demand [5, 6, 7].

2. Northern Hemisphere Energy connection
Northern Hemisphere Energy connection is mainly based on the Arctic power transmission channel. On one hand, it connects the Greenland, Norway, Barents Sea, Kara Hai, Bering Strait, while on the other hand, it is a global energy strategy platform connecting Arctic wind power base to electricity delivery showed in Figure 1.
Northern Hemisphere Energy connection not only can solve the problem of wind power transmission in the Arctic, but also can satisfy supply and demand gap of Northeast Asia, Europe and North America, taking the Bering Strait, Greenland, Norwegian Sea and Barents Sea as the fulcrums in realizing the Arctic, Europe and North America connection. This connection can give full play to great grid connection; give many benefits of peak and valley regulation, mutual backup, cross-complementarity. In addition, making use of the time difference between the continents, send the Arctic wind to other continents, meet the day peak load, and improve Arctic wind utilization efficiency showed in Table 1.

| Connection                  | Sending and receiving                                                                 | Line setting                                 | 2050 transmission capacity                                      |
|-----------------------------|---------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------|
| North Africa to Europe      | Solar power base of Morocco, Algeria, Tunisia, Libya, Egypt and other countries of North Africa to the South of Europe | Adopt ±1100 kV HVDC transmission technology  | Transmission capacity is 1.5 trillion kilowatt-hours / year; channel capacity is 300 million kilowatts. |
| Middle East to South Asia   | Solar power base of the Middle East, Saudi Arabia, Oman, the United Arab Emirates in South Asia to the western of India | Adopt UHV DC submarine cable connecting the Strait of Hormuz to reach Iran, then by land UHVDC from Pakistan to the western India Mumbai load center | Transmission capacity is 2.5 trillion kilowatt-hours / year; channel capacity is 500 million kilowatts. |
| Australia to Southeast Asia | Australian northern solar power base using high-voltage submarine cable cross-sea landing in Indonesia, and then through a short cross-sea distance through Singapore to Thailand | Adopt ±1100 kV HVDC transmission technology  | Transmission capacity is 1 trillion kilowatt-hours / year; channel capacity is 200 million kilowatts. |
3. Wind and Solar Energy Transmission Cost Model of Asia and Europe Connection

Asia is the sending (Russia Siberia, Kazakhstan, Mongolia, Xinjiang, China). Coal, hydropower, wind, solar and other energy resources are abundant. Sending has the ability of establishing of large power base, set energy to the European load centre. The connection of Asia and Europe, the transmission of wind, solar and other clean energy, use cost analysis model to measure the intercontinental transmission economy between the two continents.

3.1. The generation cost of renewable energy

The sending generation cost, is considering renewable energy generation cost and different energy delivery compound mode.

(1) Considering the characteristics of resources in each region, identify the trend of the renewable energy base construction and transportation cost.

(2) Considering the development trend of power generation technology, identify the trend of various power generation internal and external costs.

(3) Identify the costs of different electricity generation, such as hydropower, gas and coal, according to unit cost, coal price, gas price, utilization hours, tax rate, operating period, power consumption rate, annual operation and maintenance cost, and hydropower station submerged compensation.

Wind and solar power, with the variable characteristic renewable energy, bring new challenge to the power system. For the restriction of these two generation technique suffering from wind and solar, they cannot maintain better power supply balance. In the future, system and market will be united, and become the founder of renewable energy large-scale implementation. (1) Improve the net benefit of wind and solar power generation at maximum and using this benefit into the whole system. (2) Improve the management strategy, adopting the advancer renewable energy prediction method and enhancing power plant distribution method. (3) Increase the extra auxiliary work, adding demanding resource, storage, grid foundation equipment and flexible equipment usage.

According to the book of Global Energy Interconnection, in 2015, wind and solar power generation amount accounts 90% to the total new power increased. Between 2008 and 2015, the land wind power’s average cost decreased about 35%. While the solar generation cost decreased about 80%. More and more evidence showed that, the nest generation wind and solar power generation technique will be more mature, and much more economy, which can push the wind and solar into the widely usage showed in Figure 2.

![Figure 2. 2008-2015 wind and solar power generation cost curve](image)

Considering the renewable energy resource constraints, the sending side will use more renewable energy to reduce the power cost. The sending renewable energy bases, established in the area of wind and solar energy, facing the energy bundled sending out, its cost will decrease gradually. The solar energy LCOE (levelized cost of electricity) will decrease from 0.13 dollar/kw-h of 2015, to 0.055 dollar/kw-h of 2025, the decreasing ratio is 59%. The onshore wind cost will drop to 0.053 dollar/kw-h of 2025, affected by wind tower, generator, wind farm development and other factors. Consider the renewable energy cost trend, the energy persistence, fast impact the coal, gas and other fossil energy. In the future, the solar and wind power sending costs will have more advantage.
3.2. Transmission cost of channel
Transmission costs of channels depend on how to select transnational power transmission mode. The corresponding project cost and the cost of fluctuations in different countries, line loss and the cost of electricity changes in different situation.

(1) The choice of power transmission type, consider power supply and demand of inter-continent and inter-country, analyse the advantage of choosing transmission mode, analysis characteristics of UHV DC transmission project, transmission channel characteristics, utilization hours and its supporting power supply, including the grid to provide the price of transmission services

(2) Engineering cost, combined with the above project planning to estimate the static cost of construction, project cost fluctuations, the relevant technical costs of the project cost-related.

(3) The line losses cost, should be calculated on the basis of the principle of tariff balance. It is assumed that the cost of landing is the settlement price of the grid companies that provide transmission services and the grid companies in the receiving areas, which is equivalent to the cost of local power purchase.

\[ C_{\text{line loss}} = C_{\text{generation}} \times K / (1 - K) \]  

\[ C_{\text{line loss}} \] is line loss cost, \( C_{\text{generation}} \) is generation cost, \( K \) is line loss.

3.3. The receiving landing cost
The receiving landing cost refers to the sum of the renewable energy, the transmission cost, and the tariff of the line across.

\[ C_{\text{landing}} = C_{\text{generation}} + C_{\text{line}}(C_{\text{line loss}}) + T_{\text{tariff}} \]  

\[ C_{\text{landing}} \] is landing cost, \( C_{\text{line}} \) is transmission cost, \( T_{\text{tariff}} \) is tariff.

(1) Landing Cost should be calculated according to the cumulative principle of cost. Power transmission projects across continents, need to consider cross-border tariffs generated by different countries when electricity imports. Each transit country should be a link, based on DC lines, converter stations and supporting exchange projects in the country's investment were calculated transmission costs and line loss costs, the country's landing costs and based on the country's tariff rate The resulting tariffs are added together as the cost of the next country's electricity generation.

(2) There are relay points in some countries. In the landing cost calculation, the DC cost of the before relay point and the cost of electricity generated by the surplus electricity, which are taken as the DC generation cost. It can be used as after the power-weighted average of the respective country.

3.4. The landing cost competitiveness
The landing cost competitiveness refers to analysis and comparison, under the basic and global interconnection scenarios, the use of different energy combinations in the form of energy transmission area, compared with the cost of receiving electricity in the renewable energy power generation. The lower the landing cost, the more competitive the corresponding price will be. It will have the better economical; the transmission efficiency will be obviously.

\[ P = (1 - C_{\text{landing}} / C_{\text{generation}}) \times 100\% \]

\( P \) is the landing cost competitiveness.

4. Prediction
The connection of Asia and Europe has make up six intercontinental transmission schemes on two continents, which are estimated according to the investment of DC transmission project.

4.1. The prediction of power generation cost
Based on IEA and GWEC research, Mongolia wind power potential installed capacity is 1-3.1 million kW, East Gobi and Middle Gobi are 0.75-1.0 million kW. The maximum load is projected to increase to 3 million kilowatts by 2030.
Mongolia solar energy scale is about 0.37 million kilowatts, mainly concentrated in the southern Gobi, south Gobi, the East Gobi and Middle Gobi, which are rich of solar. The average radiation per square meter is 1600 kW·h. Total radiation of 570 million kW·h.

Xinjiang wind base is mainly develops Hami, Dabancheng. It predicted the wind capacity will be 20 million kW. We predicted that solar capacity will be reach 400 million kW in 2020.

4.2. The prediction of energy Tariffs

Based on IEA and GWEC research, China's tariff rate ranges from 0% to 35%, Poland ranges from 0% to 15% (average 4.2%), and Germany ranges from 5% to 17%. By the end of 2011, Russia, Belarus, Kazakhstan, the three countries jointly created the Eurasian Economic Commission, on September 1 of 2014, the weighted average tariff rate fell to 7.1%. In this research, it chooses the rate can be seen by Table 2.

| Country     | Calculation tariff (%) |
|-------------|------------------------|
| China       | 17                     |
| Kazakhstan  | 7.1                    |
| Russia      | 7.1                    |
| Belarus     | 7.1                    |
| Poland      | 4.2                    |
| Germany     | 11                     |

4.3. The loss rate prediction

Based on Ultra high power line manuscript, ± 800, ± 1100 kilovolt converter station power loss is generally between 0.5% to 1%, this research make the value as 0.75%.

4.4. The transmission cost prediction

According to the transmission scheme and power-jointed program mentioned above, combining with basic usage hours. It can get the relative transmission cost. In Table 5, one, two and three represent the
program design. 1, 2 represents different transmission type, which has different line landing port. It can get different transmission cost. These costs can show the comparison and get cost advantage.

| Table 5. The corresponding transmission cost(yuan/kWh) |
|-----------------------------------------------|
| Transmission cost 1 | one/1 | 0.126225 | one/2 | 0.140363 | two/1 | 0.135270 | two/2 | 0.149710 | three/1 | 0.185018 | three/2 | 0.201080 |
| Transmission cost 2 | one/1 | 0.078844 | one/2 | 0.081095 | two/1 | 0.078844 | two/2 | 0.081095 | three/1 | / | three/2 | / |

4.5. The landing cost
According to the relative basic usage hour and its calculation method, the landing cost can show the receiving energy price which has advantage and competitiveness showed in Table 6.

| Table 6. The relative landing cost and competitiveness analysis (yuan/kWh, %) |
|-----------------------------------------------|
| Landing cost | one/1 | 0.9905 | one/2 | 1.0566 | two/1 | 0.9121 | two/2 | 0.9699 | three/1 | 1.0768 | three/2 | 1.1694 |
| cost competitiveness | 17.46 | 11.95 | 24.00 | 19.17 | 10.27 | 2.55 |

Figure 3. Under scheme two/1 analyse the landing cost and cost competitiveness
In the scheme above, the landing cost of two/1 is lowest, and cost competitiveness is highest. While the landing cost of three/2 is highest, and cost competitiveness is the lowest. This showed that the relative landing cost of scheme two is higher than the scheme one. The relay transmission program’s landing cost is lower than the direct transmission program. The power scheme two is higher than one. The loss cost of scheme two is lower than other two schemes.

Considering the tariff of covering countries, China is the DC original point, offset the making Kazakhstan as the original point scheme’s transmission loss affection. The landing cost of scheme one and three is higher than scheme two. The tariff of scheme three is obvious high. Cost competitiveness of direct scheme cannot get the same affection with relay scheme.

Figure 3 gives the 2015-2050 landing cost and cost competitiveness. Considering all kinds of factors, as the jointed power basement reset power proportion of the scheme one and two is the same, the after generation power cost of scheme one is higher than scheme two. We can get the result is that; the lower of generation cost, the landing cost affected by generation cost will be great.

5. Conclusion
The global wind energy resources exceeds 1 trillion kilowatt, and solar energy resources exceed 100 trillion kilowatts, surpassing the human society. This research gives the northern-hemisphere energy interconnection development model, connecting Asia and Europe energy together. It also identifies the factors effecting the transmission changes cost, including generation cost, transmission cost (line loss) and landing cost. And estimate these two continents cost benefit and variable power-jointed scheme cost competitiveness. The research showed that under the northern-hemisphere energy interconnection
mode, the trans-continent mode had better benefit, and the landing cost is good to be used, can solve the pollution and energy restriction. And in the future, it will add more research focusing on the connection reasonableness.

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