Research on Benefit Evaluation System of Asia-Europe Interconnection

Jin Yanming\textsuperscript{1}, Wang Xiaochen\textsuperscript{1}, Zhao Qiuli\textsuperscript{1}, Yang Bing\textsuperscript{2} and Bian Yangzi\textsuperscript{3}

\textsuperscript{1}State Grid Energy Research Institute Co., Ltd., Beijing, China
\textsuperscript{2}State Grid Beijing Electric Power Company, Beijing, China
\textsuperscript{3}Renmin University of China, School of Environment and Natural Resources, Beijing, China

Abstract. The transcontinental interconnection will have different influence on the sending and receiving areas, which is important for making strategy. This research brings about the conception of Asia-Europe interconnection, and builds an integrated benefit evaluation model for Asia-Europe interconnection which combines energy-technology model with energy-economy models. Based on the scenario contrast analysis method, the comprehensive benefit quantitative analysis of Asia-Europe interconnection is carried out. The results show that Asia-Europe interconnection can play the complementary characteristics of various continents, realize the peak benefit, improve the utilization rate of power generation equipment, reduce system reserve capacity, which reduces system investment cost and power supply cost. Through clean substitution and electric energy substitution, it can reduce the consumption of fossil resources and the water consumption of power generation, and reduce pollutants and carbon dioxide emissions.

1. Introduction

Though Fossil energy has supported the development of industrial civilization, problems such as resource shortage, environmental pollution and climate change were brought. It has become a common choice for major countries in the world to realize green transformation of energy system and build a clean low-carbon, safe and efficient energy and power system. As wind power, photovoltaic and other renewable energy sources have the characteristics of spatial-temporal complementarity; the construction of interconnection across regions can realize the complementary of energy resources and load characteristics between two continents. With the gradual maturation of UHV and other technologies, transcontinental interconnection provides an alternative for global energy restructuring. In the future, transcontinental interconnection will have different impact on the sending and the receiving areas. In view of the current interconnection assessment, the research emphasized on technical and economic analysis, which is less focused on macro-economic impact of its. It is urgent to establish an integrated index system for benefit evaluation model of transcontinental interconnection, quantitatively analyze the comprehensive benefits and provide an evaluation tool for promoting the construction of interconnection.

This study takes Asia-Europe interconnection as an example, firstly constructs two scenarios of self-balance and Asia-Europe interconnection by using power system planning optimization approach; secondly, establishes the evaluation index system and model of the benefits of Asia-Europe...
interconnection, and finally, based on scenario analysis, analyzes environmental, economic and social benefits of Asia-Europe interconnection.

2. Scenario of Asia-Europe Interconnection

In Europe, the fossil fuels are few in reserves and the external dependence of energy is more than 50%. The local wind and solar resource are poor, and the average annual utilization hours are not high, so there may be a gap in future power supply. The EU pays attention to the energy structure transformation, as the usage of coal and nuclear power are shrinking. In Asia fossil energy is still the main energy source, with coal consumption accounting for 42%. The energy structure leads to severe environmental problems such as carbon emissions.

Based on the current situation and development strategy in Asia and Europe, the research uses the power system programming optimization model to construct self-balance scenario and interconnection scenarios, considering the boundary conditions of different clean energy development goals and transcontinental interconnection.

2.1 Self-balance scenario

To meet the demand of electricity in Asia and Europe, it is expected the total installed capacity in Asia will reach 4.19 billion, 6.94 billion and 9.75 billion kilowatts in 2030, 2040 and 2050 respectively, of which the fossil energy installed capacity will reach 38%, 26% and 23% respectively. The installed capacity in Europe is respectively expected to reach 1.82, 2.07 and 2.2 billion kilowatts.

|                | Asia       |         |         | Europe     |         |         |
|----------------|------------|---------|---------|------------|---------|---------|
|                | 2030  | 2040  | 2050  | 2030  | 2040  | 2050  |
| Coal Power     | 12.4  | 13.2  | 14.8  | 2     | 1.6   | 1.3   |
| Gas Power      | 3.6   | 4.6   | 7.6   | 4     | 5     | 5.4   |
| Nuclear Power  | 2.3   | 3.6   | 5     | 1.7   | 1.5   | 1.6   |
| Hydropower     | 7.3   | 9.4   | 12.9  | 3     | 3     | 3.6   |
| Wind power     | 10    | 27.8  | 40.6  | 4.6   | 5.8   | 6.1   |
| Photovoltaic   | 5.6   | 10.1  | 16.1  | 3     | 3.8   | 4     |
| Total          | 41.9  | 69.4  | 97.5  | 18.2  | 20.7  | 22    |

From the perspective of total power generation and power structure, in 2030, 2040 and 2050, fossil energy generation in Asia will reach 8.7, 9.3 and 11.1 trillion kWh respectively, accounting for 54%, 43% and 37% of the total power generation. Conventional non-fossil energy generation will reach 4.5, 5.8 and 8.5 trillion kWh respectively, which are 28%, 27% and 29% of the total output in Asia. The renewable generation such as wind and solar will reach 3, 6.7 and 10 trillion kWh, accounting for 18%, 30% and 34% respectively.

In the same three years, which are 2030, 2040 and 2050, fossil energy generation in Europe will reach 2.6, 2.6 and 2.5 trillion kWh, accounting for 39%, 37% and 34% of total generation respectively. Conventional non-fossil energy capacity will reach 2.4, 2.4 and 2.6 trillion kWh, and new energy generation will reach 1.6, 2.2 and 2.3 trillion kWh, accounting for 24%, 31% and 31% of total generation respectively.

2.2 Asia-Europe interconnection scenario

Under this scenario, the total installed capacity in Asia will reach 4.13, 6.82 and 9.49 billion kilowatts in 2030, 2040 and 2050 respectively, of which the fossil energy installed capacity accounts for about
38% and 25% and 23%. The installed capacity in Europe is expected to reach 1.82, 2.07 and 2.09 billion kilowatts, of which the fossil energy installed capacity accounts for 36%, 27% and 25%.

From the perspective of total power generation and power structure, in 2030, 2040 and 2050, fossil energy generation in Asia will reach 8.9, 9.0 and 10.8 trillion kWh respectively, accounting for 55%, 42% and 36% of the total electricity generation. Conventional non-fossil energy generation will reach 4.7, 5.8 and 8.7 trillion kWh respectively, which is 29%, 27% and 29% of the total output in Asia. Renewable energy generation will reach 2.6, 6.8 and 10.6 trillion kWh, accounting for 16%, 31% and 35% respectively.

Table 2. The installed capacity and structure in Asia and Europe under interconnection scenario (Units: GW)

|               | Asia          | Europe        |                |                |                |
|---------------|---------------|---------------|----------------|----------------|----------------|
|               | 2030 | 2040 | 2050 | 2030 | 2040 | 2050 |
| Coal Power    | 12.2 | 13.4 | 15.7 | 2.2  | 1.6  | 1.3  |
| Gas Power     | 3.6  | 3.8  | 4.6  | 4.3  | 4.0  | 3.9  |
| Nuclear Power | 2.6  | 3.6  | 5.0  | 1.7  | 1.5  | 1.3  |
| Hydropower    | 7.3  | 9.4  | 12.9 | 2.9  | 3.3  | 3.6  |
| Wind power    | 10.0 | 27.8 | 40.6 | 4.9  | 5.8  | 6.1  |
| Photovoltaic  | 5.6  | 10.1 | 16.1 | 3.0  | 3.8  | 4.0  |
| Total         | 41.3 | 68.2 | 94.9 | 18.2 | 20.7 | 20.9 |

According to the analysis of power balance, it is expected that Asia will form an overall pattern of transmission which is from the west to the east and the north to the south in 2030. The eastern region is dominated by electricity self-balancing, mainly developing clean energy sources such as Central Asia, Mongolia, the northern part of western China and Siberia in order to meet the electricity demand of load centers in eastern and north-eastern China; and the west of Asia will supply electricity to European load centers on the basis of meeting the electricity demand in South Asia.

3. Benefit evaluation system of Asia-Europe interconnection

3.1 Index system of benefit evaluation

The Asia-Europe interconnection will have a profound impact on power system, environment, economy and society. The benefits of the Asia-Europe interconnection are mainly reflected in the following three aspects. Firstly, the interconnection will lead to significant benefit between two continents with different time zones, different peak period and distinguished power structure. For example, West Asia will deliver low-cost electricity from large renewable energy base to countries in Europe, which lowers the supply cost in Europe. Secondly, Asia-Europe interconnection promotes the development of renewable energy resources, reduces the consumption of fossil energy and emission of air pollutant. It also increases the proportion of clean electricity from Europe, reduces the dependence of fossil energy and increases the diversity of energy supply. Thirdly, it will promote the transformation of Asia’s resource advantages into economic advantages; create new economic growth points and new jobs.
3.2 The model system of benefit evaluation

The research combines multiple energy-technology and energy-economy models, describes the influence path of Asia-Europe interconnection on the power system, economy, society and environment. We construct an integrated benefit evaluation system, expand the dimension and depth of the benefit evaluation of the interconnection and realize the quantitative evaluation of the Asia-Europe interconnection.

Considering energy-technology model, the research applies a self-developed global power planning and production simulation model, which is used to optimize the power supply construction and production plan with the objective of minimizing the total cost under the constraints of energy, policies, technical and economic characteristics. Based on scenario analysis, the paper quantitatively studies the transmission benefits and networking benefits of the interconnection. It is noteworthy that the power planning and production simulation model provides the boundary conditions such as investment cost, power cost and fossil energy consumption.

As for energy-economy model, the research improves the Global Trade Analysis Project (GTAP) model, introducing recessive cost parameter which characterizes the influence of transcontinental and global interconnection on power trade facilitation, simulates the influence of power investment and supply cost on economy and society, and evaluates the regional economic growth, employment and welfare. Dynamic GTAP model will also be a tool of global economic forecasting, which can judge the boundary conditions such as power demand through economic forecasting, give feedback to energy-technology models.

As for climate evaluation model, the research applies Integrated Assessment Model to simulate the influence of carbon emission of power sector on global temperature and sea level under self-balance scenario, and analyses whether they can achieve the 2°C temperature-rising target. Based on life cycle analysis, we compare energy consumption of different power generation technologies, establish environment assessment model of the global interconnection, and evaluate the impacts of different development paths on the environment from the aspects of water, land and various pollutants.
Figure 2. Model for evaluating the benefit of interconnection

4. Asia-Europe interconnection benefit assessment

4.1 The benefit of power system

Compared to self-balance scenario, thermal Power Installation in Asia and Europe will reduce 360 million kW, which saves 160 million yuan on system fuel cost in 2050. Under the influence of large-scale development of renewable energy and technology progress, power cost of Asia-Europe interconnection will decline over time and will drop by 0.79 cents/kw in 2050.

4.2 The benefit of economy and society

The simulation results show a win-win situation after Asia-Europe interconnection. The research claims that the interconnection results in a significant economy boost in sending area. In the short run, it is mainly due to the investment shift to sending area. Asia-Europe interconnection in 2030, 2040 and 2050 will boost Asian GDP growth by 0.07%, 0.35% and 0.22%, compared to the self-balance scenario. As for receiving area, the decline of investment will have a negative impact on economy. Compared with the self-balancing scenario, Asia-Europe interconnection increased European GDP growth by about 0.02, 0.08 and 0.04 percentage points in 2030, 2040 and 2050.

In terms of employment, as investment on electricity drives the development of secondary industry, more labor is transferred from agriculture to industry, the employment opportunities also increase. Compared to the self-balance scenario, the Asia-Europe interconnection will boost employment in Asia by 2, 4.5, and 3.9 million in 2030, 2040, and 2050.

4.3 The benefit of energy and environment

4.3.1 Energy resources saving

The interconnection can save the fossil energy resources by applying clean energy and electricity as substitution. Compared to the self-balance scenario, as of 2030, 2040 and 2050, the Asia-Europe interconnection will save fossil energy resources for about 200 million, 630 million and 5.9 billion tons Tec, with a reduction of about 0.5%, 0.9% and 5.9%. Interconnection brings benefits such as load complementarity in Asia and Europe. By 2050, thermal power generation in Asia will have been reduced by a cumulative total of 17.0 trillion kWh, equivalent to about 4.9 billion tons Tec. The Europe receives large-scale clean electricity from Asia, replacing local fossil energy and thermal power generation of it will be reduced by 5.1 trillion kWh, which is about 1 billion tons Tec.

The interconnection also reduces the water consumption by promoting the development of clean energy and reducing the construction of coal and gas power station. Compared with self-balance scenario, by 2030, 2040 and 2050, water consumption will have been reduced by 51 billion, 150 billion and 1.223 trillion tones, which the reduction percentages were 0.4 percent, 0.7 per cent and 3.9 percent, respectively.
The interconnection also saves land resources as the installation will reduce. Compared to self-balance scenario, by 2050 the Asia-Europe interconnection will have a cumulative land saving area of 194 billion square meters, of which 193 billion from Asia and 1 billion from Europe.

4.3.2 Pollution reduction
We calculate the emission level of sulfur dioxide (SO2), nitrogen oxides (NOx) and particle matter (PM) in self-balance scenario based on the emission standards in each continent. Compared to self-balance scenario, the Asia-Europe interconnection will have reduced SO2 emission by 0.24, 0.67 and 5.24 million tons in 2030, 2040 and 2050, with reduction rate of 0.7%, 1.2% and 6.3%, reduced NOx emission by 0.6%, 1.1% and 6.2% for 0.25, 0.74 and 6.05 million tons, reduced PM emission by 0.7%, 1.2% and 6.3%, for 0.05, 0.14 and 1.06 million tons.

With the interconnection of Asia and Europe, the energy structure shifts to clean and low-carbon side, which lead to the reduction of fossil energy consumption. In 2050, the share of clean energy generation will reach 60% in Europe and 66% in Asia. Based on the life cycle factors of carbon emission under different technologies, greenhouse gas emission reduction will reach 700 million tons in total from 2016 to 2030, with 0.6% reduction rate compared to self-balance scenario.

5. Conclusions
The contributions of this study are as follows. Firstly, it analyzes the influences of Asia-Europe interconnection on power system, ecosystem, economy and society, establishes an integrated index system for benefit evaluation. Secondly, it combines energy-technology and energy-economy models, establishes a comprehensive benefit evaluation method of interconnection which is characterized by clean substitution and electric energy substitution. Thirdly, it quantitatively analyzes the benefits of transcontinental interconnection. The conclusion can provide reference for promoting the construction of transcontinental grid.

It is noteworthy that the research provides the analysis framework and method for the impact of transcontinental infrastructure construction on the energy environment, economy and society. The results are closely related to the boundary condition settings and the scenario assumptions.

References
[1] Z.Y. Liu, Research and Prospect on Global Energy Internet[J].Proc. CSSE 19, 5103-5110 (2016)
[2] J. Wu, X.D. Zhu, Y. Zhang, Economic Evaluation Method for Global Interconnected Power System [J].Smart. Power. 12, 6-11 (2017)
[3] International Renewable Energy Agency. Renewable energy benefits: measuring the economics[R].IRENA, 2016.
[4] Z. M. Pu, The effect of greenhouse gas reduction policy on global economy [M].BJ. Sci. Pr. (2017).
[5] Y.M.Jin, X.TAN, B.Q.Jiao,et al., Study on Economic and Social Benefits of Global Energy Internet Based on Computable General Equilibrium Model[J].Smart Power.5,1-7 (2018)
[6] G.H. Xie, N.N. Li, X.L. Wang, et al., Study on Development Potential of Global Large Scale PV Power Base [J].Smart Power. 4, 1-5 (2018)
[7] J. Macknick et al., Operational water consumption and withdrawal factors for electricity generating technologies: a review of existing literature [J].Environ. Res. Lett., 7, 189-190 (2012)