Research on the affection of imported electricity on power system security and environmental treatment

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Abstract. Nowadays, Zhejiang Province proposed a plan to establish national CO₂-free energy demonstration province, which plan put a slogan of “Reasonably introduce imported electricity and effectively enhance the network security”. The paper analyzes the reasonable power ratio in Zhejiang Province during “13th Five-Year” from two aspects: power system security and environmental treatment. For power system security, we focus on the stability characteristics under high imported electricity. For the environmental treatment, the influence of imported electricity on total coal consumption and energy conservation index are shown. In addition, the EXMOD model is applied to quantize the social environment benefit.

1. Introduction
Nowadays, the energy development is in a critical period of profound changes and major adjustment. With the change of the energy supply and demand pattern and new trend of international energy development, vigorous develop of CO₂-free energy has become the inevitable trend of energy development. In order to ensure the national energy security, we should execute revolution of energy production and consumption. At the APEC meeting, China and the United States signed a joint statement with the two targets: (1) China's carbon dioxide emissions reach peak level around 2030. (2) Non-fossil energy increased to about 20% of the primary energy consumption[1].

Zhejiang province government explicitly put forward strategy of beautiful Zhejiang construction and significantly raising living standards[2]. In 2013, Zhejiang province government issued action plan of air pollution prevention and control, which determine the target of adjustment of energy structure.

Imported electricity channel is increased with the rapid development of ultra-high voltage transmission project in Zhejiang province. In 2015, imported electricity resources to Zhejiang province is about 16.94 GW, accounts for about 27% of the maximum load of the whole society [3-7]. Imported electricity is of great significance to adjust the energy structure of Zhejiang province emissions reduction. However, imported electricity brings great challenges to the safe and stable operation of Zhejiang power grid.

The paper analyzes the influence of imported electricity from two aspects such as power grid safety and environmental benefits. The organization of paper is as follows: In Section II, imported electricity resources and channels are introduced. In section III, PSD-BPA is applied to analyze the influence of imported electricity on stability of power grid. In Section IV, EXMOD model is employed to evaluate
social environmental benefits of imported electricity on Zhejiang province. Finally, the paper draws the conclusions in Section VI.

2. Imported electricity resources and channels of Zhejiang province

2.1. Imported electricity resources
In 2015, imported electricity resources to Zhejiang province is about 16.94 GW. Imported electricity resources has four major sources as follows.(1) The three gorges hydropower station, located in Yibin city of Sichuan, which is the world's biggest hydropower project, has installed capacity of 22.4 GW. (2) Xiluodu hydropower station, which is the "twelfth five-year" key construction projects and "west-east electricity transmission project "backbone power source, has installed capacity of 13.86 GW. (3) Electricity from Anhui Province to East China, has installed capacity of more than 10 GW. (4) Sichuan water is an important part of "west-east electricity transmission project ".

It is estimated that imported electricity to Zhejiang province will increase 23 GW for the next five years, accounted for 44% of the highest load in the whole society.

2.2. Imported electricity channels
In 2016, State Grid Corp. will put Lingzhou-Shaoxing HVDC transmission project into operation, which has converter capacity of 8 GW. Anqing-Zhejiang and Nanchang- Zhejiang UHVAC power transmission will put into operation.

3. Safety analysis of imported electricity on Zhejiang power grid.

3.1. Calculation condition
In order to analyze maximum imported electricity to Zhejiang power grid, the article analyze 2016, 2020 normal peak load operation mode. Chinese electricity academy PSD - BPA is applied as analysis tool. Fault types are as follows[8-10]:

- 500 kV and 1000 kV ac line N - 1 fault: three-phase grounding fault occurred in 0 cycle, circuit breaker trip off at 5 cycles on one side, and circuit breaker of the other side trip off at 6 cycles.
- DC system fault: bipolar block and monopoles block occur at 0 cycle.

Stability criterions are as follows:

- Power angle stability: Synchrony motors should be avoid operating asynchronously.
- Voltage stability: Duration of bus bar voltage below 0.75 p.u. after eliminate failure should be less than 1 second.
- Frequency stability: System frequency collapse cannot happen.

3.2. Calculation result

3.2.1. Static stability
After calculation, at peak load time in summer of 2016, static stability margin of Zhejiang power grid is more than 8% at normal operation mode, and more than 5% at accident condition, which satisfies the operation requirements of power grid.

3.2.2. Transient stability (AC fault)
In 2016 and 2020, the system can keep stable and meet the requirements of the guide rule at the condition of 1000 kV lines and transformers, 500 kV lines and transformer three-phase permanent N-1.

3.2.3. Transient stability (DC fault)
The system frequency drop to 49.95Hz after Yibin-Jinhua DC bipolar block and recover to 49.92Hz in summer of 2016, while system frequency drop to 49.95Hz after Yibin-Jinhua DC bipolar block and recover to 50.09Hz in summer of 2020.
4. Environmental benefits analysis of imported electricity

4.1. Influence of imported electricity on coal consumption

In 2014, coal consumption of Zhejiang province is about 138.24 million tons, which fell 2.4% year-on-year. Coal consumption used in thermal power, heating, and other energy processing transformation activities is about 107.33 million tons, accounting for about 78% of the total coal consumption, while scattered coal consumption is 30.91 million tons, accounting for 22%. In 2014, standard coal consumption of thermal generation with capacity of 6000 MW or above in Zhejiang province is 275 g/kWh, which is used in this paper to evaluate coal consumption.

In 2020, the whole society electricity consumption of Zhejiang province is 502.5 billion kWh. When external power is accounted for 34%, the province's coal consumption is 74.16 million tons, which is decreased by 2.7% compared with 2015. Through analysis, coal consumption can reduce about 8.31 million tons if foreign electricity increases 1%.

4.2. Environmental benefit analysis

Zhejiang electric power industry has been committed to the governance of coal consumption. However, the high cost and technical difficulty of the current dust control, and immature carbon dioxide treatment technology lead pollutants can not be completely harness. It still needs to spend a lot of cost to eliminate the influence in future[11-12].

In order to consider environmental impact in project decision-making process, the paper applies the American Boston Tellus institute development EXMOD model to analyze the environmental impact of dust pollution in Zhejiang province. The environmental impact of quantitative divided into the following three steps:

1. Summary and analyze the main environmental factors and pollution sources in Zhejiang Province, and select major indicators.
2. Assess the value of the environmental impact factors;
3. Quantify environmental benefits, which can be incorporated into the economic analysis and decision-making of the project.

After determining the environmental factor, next job is monetization of environmental factors lead to physical damage. EXMOD model provide the environmental costs per capita in 2015 calculation formulation, which equals to environmental costs per capita in 2003 plus nominal GDP per capita in 2015 divide nominal GDP per capita in 2003.

| Table 1. unit economic value of emissions in Zhejiang province (yuan/1000 tons per person). |
|-----------------------------------------------|
| Year | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| lower limit | 1.81 | 1.94 | 2.08 | 2.22 | 2.38 | 2.55 |
| upper limit | 2.72 | 2.91 | 3.12 | 3.34 | 3.57 | 3.83 |

| Table 2. environmental effect cost in Zhejiang province (One hundred million yuan/ten thousand tons). |
|-----------------------------------------------|
| Year | lower limit | upper limit | average |
| 2016 | 1.45 | 2.17 | 1.81 |
| 2017 | 1.48 | 2.22 | 1.85 |
| 2018 | 1.52 | 2.28 | 1.90 |
| 2019 | 1.55 | 2.33 | 1.94 |
| 2020 | 1.59 | 2.39 | 2.00 |
"Benefit" transfer method is used to calculate Zhejiang environmental costs. The related data is shown in table 1. Utilize EXMOD model to calculate the dust pollution in Zhejiang province environmental costs, which is shown in table 2. The results demonstrate that environmental impact costs will rise year by year with the development of Zhejiang economy and GDP per capital.

Through calculation, environment impact cost caused by coal dust pollution in Zhejiang province is about 192 Yuan/tons. In period of 13th Five Year, it can save 8.31 million tons of coal for electricity generation in the province, reduce dust emissions about 80000 tons and generate environment comprehensive benefit about 1.6 billion Yuan with 1% increase of imported power.

It increase 118.2 billion kWh imported electricity in 2020 compared with 2015, which can reduce dust emissions about 440000 tons and generate environment comprehensive benefit of 8.8 billion Yuan.

5. Conclusions
In Zhejiang province, increasing imported electricity into the Zhejiang province play a significant role in promoting energy conservation and emissions reduction. Through power grid stability analysis and the social environment economic efficiency analysis, we can draw the following conclusions:

1) Through the safety analysis of Zhejiang power grid at peak load in the summer of 2020, the security and stability of Zhejiang power grid satisfy requirements of power grid operation in the case that imported electricity power accounted for 44%.

2) In period of 13th Five Year, it can save 8.31 million tons of coal for electricity generation in the province, reduce dust emissions about 80000 tons and generate environment comprehensive benefit about 1.6 billion Yuan with 1% increase of imported power. It increase 118.2 billion kWh imported electricity in 2020 compared with 2015, which can reduce dust emissions about 440000 tons and generate environment comprehensive benefit of 8.8 billion Yuan.

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References
[1] Rhodes Christopher J 2016 The 2015 Paris climate change conference: COP21[J]. Science progress 99(1) 97-104
[2] Conglin, Huang Shan Wu Qianbo Pan 2013 Development Experience of Foreign Rural Area and Analysis on the Beautiful Countryside Building in Zhejiang Province [J]. Huazhong Architecture 5(7) 31
[3] Hirschberg R. Dones U, Ganter S 1999 Environmental inventories for future electricity supply systems for Switzerland[J]. International Journal of Global Energy Issues 12(1-6) 271-282
[4] Vehmas J, Kaivo-oja J, Luukkanen J, et al 1999 Environmental taxes on fuels and electricity—some experiences from the Nordic countries[J]. Energy Policy 27(6) 343-355
[5] Peacock A D, Newborough M 2006 Impact of micro-combined heat-and-power systems on energy flows in the UK electricity supply industry[J]. Energy 31(12) 1804-1818
[6] Farhat A A M, Ugursal V I 2010 [J] International Journal of Energy Research 34(15) 1309-27
[7] Itten R, Frischknecht R, Stucki M, et al 2012 Life cycle inventories of electricity mixes and grid[J]
[8] Ulbig A, Borsche T S, Andersson G 2014 Impact of low rotational inertia on power system stability and operation[J]. IFAC Proceedings Volumes 47(3) 7290-7297
[9] Brandt S, Kalverkamp F, Heßler R, et al 2017 Challenge of retrofitting old decentralised power plants in Germany in terms of power system stability[J]. CIRED-Open Access Proceedings Journal 2017(1) 1618-1620
[10] Chen H, Shi L, Ni Y 2017 Solution of voltage stability assessment for complicated power system incorporating wind power[J]. The Journal of Engineering 2017(13) 2292-2297

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[11] Fouquet D, Johansson T B 2008 European renewable energy policy at crossroads—Focus on electricity support mechanisms[J]. *Energy policy* **36**(11) 4079-4092
[12] Ouédraogo I M 2010 Electricity consumption and economic growth in Burkina Faso: A cointegration analysis[J]. *Energy Economics* **32**(3) 524-531