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Cost of long distance electricity transmission in China☆

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ABSTRACT

China's energy resources reserves are concentrated on the central and western regions. Meanwhile, the major energy demand is distributed in the eastern region. Large scale of cross-regional electricity transmission is implemented to guarantee the power supply. The long distance electricity transmission (LDET) cost is an essential component of the final detail price. This paper proposes a new method to evaluate the real cost of LDET, which mainly focuses on the price mark-up between the electricity exporter and importer. A weighted least square regression model is applied to evaluate the influence of the factors that could impact the real operating cost of the LDET. Furthermore, we apply the LDET cost model to evaluate the synthesize cost of renewable energy, and find the current renewable policy of China is inefficient.

1. Introduction

In 2011, China's total generating capacity reached 4.47 trillion kilowatt-hour (kWh), surpassing the 4.1 trillion kWh of the United States, and becoming the largest electricity consumption country in the world (National Bureau of Statistics of China, 2012). Meanwhile, the distribution of power resources is imbalanced, which means load center of electricity is usually far away from the supply side. In 2014, the annual cross-transmission of electricity in China was 274.1 billion kWh. The interprovincial transmission volume of electricity was 842 billion kWh, which accounted for 15.3% of the total electricity consumption (China Electricity Council, 2015). Meanwhile, the electricity demand still keep growth fast with the growth of economic (Lin and Liu, 2016). To this end, huge resources were invested in transmission lines each year. As we can see in the Fig. 1, the grid investment exceeded the generator investment since 2013, and the growth rate of grid is higher than the generator.

The transmission and distribution (T & D) of electricity are deemed as a natural monopoly industry. In China, the T & D network is monopolized by two giant institutions: State Grid Corporation of China and China Southern Power Grid. As nature monopoly industry, the efficient of electricity transmission demand relies on monopoly supplier (Kaserman and Mayo, 1991; Joskow, 1997). Meanwhile, the government should regulate the electricity price according to the T & D cost.

The pricing of transmission is an important work of regulation. The last cycle of China's electricity market reform was implemented in 2002 (Ming et al., 2013), which had proposed to accounting the transmission price independently. In fact, since there is no competitive electricity market in China, the T & D cost is opacity to the public. Wang and Chen (2012) figured out that the monopoly in China's electricity market will be harmful to public welfare. In order to improve the regulation mechanisms of T & D industry, the Chinese government launched a new round of reform for the electricity market since 2015 (Zeng et al., 2016). In March 2015, The State Council of China (2015) released a document named “the several opinions for the further reform on electricity market”, which indicated that the goal of the electricity reform was to separate the T & D process from retailing. One of the key points of the electricity reform is to check the real costs of T & D. In March 2016, The National Development and Reform Commission (2016) published executive orders to require the grid submitting the base price of T & D before October 2016.

In practice, it's very hard to find out the real cost of electricity transmission due to the power grid is a complex network, and there exist kinds of cross subsidizations and circuits (Brown and Sedano, 2004). The cost contains the investment and transmission loss in the transmission line and the transformer substation. The previous studies major focus on the transmission loss. Conejo et al. (2002) compared the different practical algorithms of transmission loss. Tan and Lie (2001) considered the loss cost in the electricity price. Few literatures

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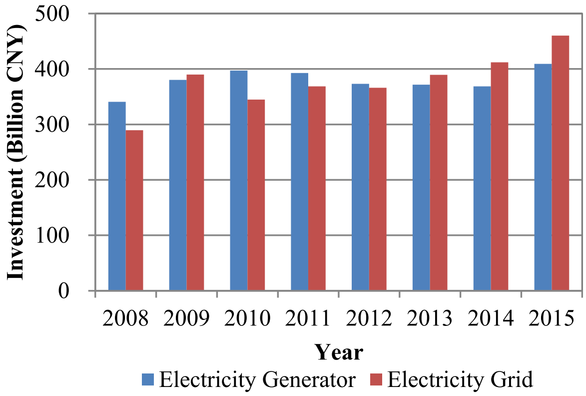

Fig. 1. Investment in electricity generator and grid.

focus on the real running cost of transmission. Li et al. (2015) compared the technology and costs between coal transportation and electricity transmission. But the calculation methodology of electricity transmission cost is not described in their papers. He et al. (2015) analyzed the electricity transmission and distribution tariff mechanism from the point of view of sustainable development. Besides, some researchers focus on the transmission cost combined with renewable. Labordena and Lilliestam (2015) considered the transmission cost of solar electricity from desert. You et al. (2016) considered the transmission expansion with wind power.

The main contribution of this article is that a new methodology to estimate the real cost of LDET is proposed. In our theory, the market price reflects all the factors that may impact the cost, and we can estimate the final cost from the price markup between different districts. From the financial statements of the state grid, we can see that the economic profit of the grid is close to zero. In general, the difference of the marginal feed-in tariffs between different provinces reflects the real cost of electricity transmission. Due to the transmission capacity between provinces is different; this paper uses the weighted least square (WLS) method to deal with this problem.

Besides the factor of long distance electricity transmission (LDET) cost, the price mark-up may also be affected by the relation between market supply and demand. In general, the lower the local electricity supply ratio is, the higher price mark-up will be. In addition, a high peak-valley price deviation can reflect the imbalance of intra-day electricity demand, and may increase the electricity supply cost. This paper adds two dummy valuables to consider the impact of these two factors.

According to the regression model, we can estimate the final real cost of the LDET. Though this method ignores the micro details in the power network, the results can reflect the overall cost from supply side to demand side. The LDET model considers the marginal cost of the transmission distance and provides benefit information for the policy maker. For example, the LDET cost model can be applied in some macro level analysis such as the analysis of power generator allocation. This paper illustrates two application cases to show how the LDET cost model can be applied in the policy evaluation. By internalize the external LDET cost, we can draw a conclusion that the current renewable energy policy provide a distorted incentives and cause inefficient power allocation.

The rest of the paper is organized as follows. Section 2 explains the analysis framework of this study, including the description of the basic assumptions, methodology and data sources. Section 3 presents the results of the study, including the optimal transmission volume and path, and the WLS regression result. Section 4 followed by a discussion. Some application cases are also presented in this part. Conclusions as well as recommendations for future analysis are drawn in Section 5.

2. Methodology and data

The power grid is a network which contains many circuits. To accurate evaluate the cost of LDET, it may need to implement the power flow analysis and analyze the cost of each circuit. But for some applications, such as policy evaluation, we may only concerns about the cost of net transmission, which can be seen as final cost. This section proposes a new method to calculate the final cost of LDET base on some rational economic assumption, which ignores the complicated process and only reflects the cost of the net transmission.

2.1. The basic assumption

To estimate the cost of LDET, we need to know the transmission relationship between each district. In reality, the cost data of LDET is not open to the public, and even the regulator. We can only acquire the electricity balance data of each province. The net transmission volume between each province is unknown. In addition, some provinces only play the role as intermediate, which making the problem more complicated. To get the datasets of regression, we need to make some reasonable assumptions.

Assumption 1. The power grid is a rational economic agent. The choice between LDET and local supply follows the principle in Eq. (1). Where C_i means the marginal electricity feed-in tariff of the electricity input province; C_o means the marginal electricity feed-in tariff of the electricity output province; C_T mean the cost of LDET. This equation imply that if the cost of long distance transmission is lower than the cost of local supply, the power grid will increase the volume of long distance transmission. When in the condition of market clear, the cost of LDET will equal to the cost of local supply.

$$C_i = C_o + C_T \tag{1}$$

In fact, the electricity price markup may be affected by other factors such as power demand of the electricity input province. So if we focus on the single line, we will find that the price markup may be not consistent with the difference of marginal electricity feed-in tariff, which means there is large cross-subsidization between each transmission line. But for the whole grid, the total profit is close to zero, and the total price markup can reflect the total LDET cost of the grid.

Assumption 2. The principle of electricity dispatching is minimizing the total transmission distance which is shown in Eq. (2). We will demonstrate in Section 2.3 that the minimal transmission distance problem is equivalent to the maximize profit problem under certain condition. The subscripts i and j represent the electricity output and input province respectively. The symbol d_{ij} represents the distance between i and j; t_{ij} means the transmission volume between i and j. The optimization problem is under the constraints in Eq. (3). The symbol O_i is the total output capacity of i, and the symbol I_j represents the total input requirement of j.

$$\min \sum_{i,j} d_{ij} t_{ij} \tag{2}$$

$$s.t. \sum_{j} t_{ij} = O_i \; i = 1, 2, \ldots, n$$
$$\sum_{i} t_{ij} = I_j \; j = 1, 2, \ldots, m \tag{3}$$

It should be mentioned that the constraint of input/output volume is base on the real transmission data. In practice, the electricity exchange between different districts may affected by other factors such as policy and monopoly. The realistic electricity input and output of each province is a result of these impacts. The constraint of Eq. (3)