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Coal power overcapacity in China: Province-Level estimates and policy implications

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ABSTRACT

Since the project approval right was decentralized from the central government to the local governments in 2014 in China, a large quantity of coal power projects has been approved and built, resulting in low operation efficiency and calling for strict de-capacity policy. In this paper, we estimate coal power overcapacity with a cross-province power and energy balance model. We estimate the overcapacity situation in 2015 at 140–160 GW with a comprehensive dataset. The 2020 overcapacity scenario is estimated with detailed representation of official planning and new projects under construction. The results show that there is a general trend of growing overcapacity in most provinces by 2020 and the national excess scale will be around 210 GW under the basic scenario and may even reach 240–260 GW under a High scenario. Relevant policy suggestions are put forward to address the overcapacity issue.

1. Introduction

Cutting down the share of coal power in China's energy structure is key to achieve low-carbon energy transition and reduce the risks associated with climate change (Pan et al., 2012; Stewart, 2014; Torvanger and Skeie, 2008; Michael and Heather, 2011; Hu and Huang, 2016; Li and Yan, 2014; Su and Fang, 2016). Meanwhile, with the economic restructuring during the 12th Five-Year-Plan (FYP), the Chinese economy has entered the 'new normal', and the growth of electricity demand has slowed down (Tang et al., 2016; Yuan et al., 2016a). In 2016, and the growth of electricity consumption was only 0.96%, which casts a shadow on the prospect of coal power. In order to achieve a clean energy structure and reduce carbon emissions and realize the commitment that China should peak its carbon emissions by 2030 made by Chinese government (Yao et al., 2016), strict control on coal use has been implemented in China, substantial financial support has been given to renewable energies and the priority has been switched to the utilization of new energies, such as wind, solar power and so on (Ouyang and Lin, 2014). Actively supported and encouraged renewable energies have become a strong competitor, restricting the growth of coal consumption. However, since the approval right of coal power project was decentralized from the central to the local governments in 2014, a large number of new projects has been approved and built (Yuan et al., 2017), which results in a large number of coal-fired units staying in idle state and the number of utilization hour decreasing significantly from 4739 h in 2014 down to 4165 h in 2016 (CEC, 2014; CEC, 2016) and with the building of new projects, the situation might be more serious (Yuan et al., 2016a). The problem of coal power overcapacity has aroused intensive concern from the academia and Chinese government

In view of coal power overcapacity in China, many experts and scholars at home and abroad have carried out relevant researches (Hu et al., 2010, 2013; Zheng et al., 2014; Zhang et al., 2017; Lin et al., 2018). Within China, operating hours (or "utilization hours") are often used as the principal indicator of overcapacity. However, operating hours are a measure of asset utilization, and do not necessarily provide information about reliability or economic efficiency (Lin et al., 2018). For instance, an electricity system with large amounts of hydropower, wind, or solar generation may have low utilization in average. Another, more accurate way of measuring overcapacity would be reliability metrics. Typically, reliability studies calculate the probability of power outages in the high-voltage transmission system, given demand characteristics and the probability of unexpected generator failures. This probability, referred to as a loss-of-load probability, requires detailed information on electricity demand (loads) and generator failure probabilities. This information is, however, not publicly available in China. An alternative approach is to use reserve margins, which can evaluate power grid reliability and generating capacity needs at the same time.

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Hu et al. (2010, 2013) proposed Integrated Resource Systematic Planning (IRSP) model for power planning in China. Zheng et al. (2014) and Zhang et al. (2017) expanded the model to include more elements like demand response and transmission network. However, all these proposed planning models are data intensive and subject to practical limitations. On the other hand, the typical unit commitment and dispatch model or even simpler screening model require the input of load profile and unit output characteristic data, which is usually unavailable and subject to transparency concern (Davidson et al., 2016; Yuan, 2016). With regards to optimal capacity expansion, some scholars have pointed out that even though many models are directed towards optimal least cost planning, they are constrained by complex conditions and nonlinear factors, leading to large uncertainty in the modeling results. Meanwhile, restricted by political and environmental factors, the accuracy of medium-and-long-term power planning is harder to achieve, and optimal power planning is still merely an ideal (Antunes et al., 2004; Li et al., 2006). To measure coal power overcapacity, for practical concern a simplified model can be more transparent and convincing, though it may not meet up with optimal planning. Based on reserve margin rate, (Tang et al., 2016; Hao et al., 2015) predicted the ceiling of the development of the coal, which considered the balance effect of power substitution and energy saving efficiency from the perspective of power demand and concluded that China's demand for coal will peak around the year of 2020. Some authors (Yuan et al., 2016a,b; Yuan and Na, 2016 Zhang and Bai, 2016) further described the coal power overcapacity in china, concluded that China's coal power overcapacity will reach 200 GW by 2020 and briefly analyze the coal power overcapacity in China's six regional grids. Further, in view of the issues caused by coal's overcapacity, Zhao et al. (2017) used the LCOE (the levelized cost of energy) and project evaluation model for national survey from the economic perspective and concluded that the internal rate of return of new coal power projects in most provinces would be lower than the industry average if all the new projects were built by 2020. However, the existing quantitative work on coal overcapacity is mainly studied at the national or regional level (Lin et al., 2018; Yuan et al., 2016a,b; Yuan et al., 2017). Since the main body of the administrative unit in China is the provincial government, the study of the regional level cannot help implement the regulation policy. In addition, the determination of the target of reducing overcapacity needs to be based on consistent expectation of electricity growth by the government. Therefore, to provide solid support to de-capacity policy, it is necessary to carry out quantitative research on the overcapacity scale in provinces according to the official power demand forecast scenario and the latest information on coal power project under construction.

In the face of the increasingly serious problem of coal power overcapacity, China began issuing policies to regulate coal power from April 2016 (Power Polaris Network, 2016a,b; CEC, 2017b; Power Polaris Network, 2017b). In March of 2017, Chinese premier Li Keqiang clearly required to implement de-capacity policy in coal power sector in his report on the work of the government in 2017 (GOV, 2017). The series of policies mainly consist of “Notice on further eliminating the backward production capacity of coal-fired power industry”, “Notice on Promoting the Orderly Development of Coal power in China” and “Establishing an Early Warning Mechanism for Coal Power Planning and Construction and Publishing 2019 Notice of Coal Mine Electricity Planning and Construction Risk Warning” in April 2016, “Notice on Further Regulating Coal Power Planning and Construction” in October 2016, “Notice of Risk Warning of Coal Power Planning and Construction in 2020” in April 2017, “Notice of the List of Projects Stopping and Postponing Construction of Coal power in the Province" in September 2017. Efforts have been made from eliminating the backward coal power capacity to limiting new projects. To date, it is evident that new construction has been postponed or stopped, but a consensus on the scale of overcapacity at province level must be reached before further policy can be formulated.

The literature review indicates that a power & energy balance model on provincial level would be an appropriate tool for our study, capturing the most salient features of power planning while providing high-level and transparent modeling work to support policy making. The work of this paper is organized in the following three aspects. Firstly, taking each province as a research unit, three indexes, i.e. the actual reserve margin, excess scale and utilization hour of coal-fired units are selected to evaluate the overcapacity situation of each province based on most recent data. Secondly, considering different situations of load growth, new energy installation, inter-province power exchange and the resource adequacy (see definition in Section 2.1.1) value of hydropower, the overcapacity situation of coal power in each province in 2020 is studied and the upper and lower bound is estimated based on comprehensive scenario analysis. Finally, the national overcapacity situation is summarized and policy implications for de-capacity policy and market reform are provided. The rest of this paper is organized as follows. Section 2 presents the model, data and key assumptions. Section 3 reports the estimate results for 2015 and 2020 and conducts sensitivity analysis for the 2020 scenario with several key variables. Section 4 concludes the paper with policy implications.

2. Model and data

2.1. Evaluation model for coal power overcapacity

The electric power and energy balance is the basis of power system operation. Based on the actual operation mode of power system, indexes such as types and utilization hour of power plants, electricity consumption and load on provincial level, and inter-province power/energy exchange should be included in the evaluation model. The model detail is as follows.

2.1.1. Model constraint

Constraint 1: Energy balance

$$W - \sum P_i \times S_i - W_{in} + W_{out} \geq 0(i = 2, 3...7) \quad (1)$$

where,

W: the electricity consumption, only refers to the electricity consumed in one certain province, including the electricity generated locally and the energy transmitted from other provinces.

P_i : the installed capacity of other power types including hydropower, wind power, solar energy, nuclear power, denoted as $P_2 \ldots P_7$.

S_i : the utilization hour of other types of power sources including hydropower, wind power, solar energy, nuclear power, denoted as $S_2 \ldots S_7$.

W_{in} and W_{out}: the equivalent energy import/export of inter-province exchange.

Constraint 2: Electric power balance

$$\sum P_i \times \alpha_i + P_{in} - P_{out} - P_m \geq 0(i = 1, 2...7) \quad (2)$$

where,

α_i: the resource adequacy value of coal power, and other types of power sources, denoted as $\alpha_1 \ldots \alpha_7$; here resource adequacy is defined as the ability to supply load with adequate generation resources, traditionally defined as ability to provide adequate supply during peak load and generation outage conditions (IEA, 2014);

P_i: the installed capacity of coal and other types of power sources, denoted as $P_1 \ldots P_7$;

P_{in} and P_{out}: the equivalent import and export power of inter-province exchange;

P_m: the maximum power load.

When the constraints of above model are satisfied, there will be a detailed description of three evaluation indexes, i.e., the reserve margin, overcapacity scale and utilization hour of coal-fired units.