Coal-fired Power Generation Development Trend in China by 2050

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Abstract. China's coal-fired power exhibited overcapacity as its utilization hours significantly decreased. The paper analyzes reasons for the overcapacity, pays special attention to the coal-fired power capacity needed in the energy transition of China in the middle and long term. Analysis shows that, without consideration of drop-off cost, around 980 GW coal-fired power capacity is enough to meet the demand and ensure the power system balance. If we optimize the power system by least total cost, the reasonable capacity of coal-fired power will be 1120 GW, somewhat larger since of the role changing and price advantage. And the peak capacity of coal-fired power will reach 1149 GW in 2026, compared with it power generation reach the peak in 2025. Since of declining utilization hours, coal-fired power will accelerate the drop-off after 2030.

Introduction

In recent years, the role coal-fired power played in the power sector has been weakened as the result of supply restructuring. From 2010 to 2016, the average growth rate of China's thermal power generation was 4.5%, yet its proportion in the total generation has declined from 79.9% to 72.4% [1, 2]. Besides, the utilization hours of the thermal power units decreased to 4165 hours in 2016, which is the second year since 2015 to be less than 4500 hours [2]. (In China’s statistics, thermal power data is usually used instead of coal-fired power data. Since both installed capacity and power generation of coal-fired power account for more than 90% of total thermal power, it uses thermal power data here for the absence of data associated with coal-fired power.)

It's worth noting that in 2016, China's wind power generation accounted only for 5.1% of the total generation which had very limited impact on the role and operation of coal-fired power plants. With the rapid development of renewable energy generation in the future, there will be more challenges for the existing and growing coal-fired power plants.

Take a look at other coal-fired power dominated countries. The average utilization hours of the coal-fired power plants in Australia, Greece, Germany, India, South Korea and South Africa were 5994, 5848, 4999, 5694, 7033, 5694 hours in 2015[3], all of which were higher than that of China. The average utilization hours of these coal-fired power plants in the above-mentioned countries were 5877 hours, higher than the designed benchmark level 5500 hours in China. The utilization hours in China accounted for 70.9% of that average level and 75.7% of designed benchmark level.
**Main Reasons for Coal-fired Power Overcapacity**

First, due to the slowdown of electricity demand growth under the new economic norm, the overcapacity of electricity supply is becoming general. In recent years, China's regional power demands grew at rates lower than expected, while some areas even exhibited negative growth rates. Consequently, the power supply and demand situation has transferred from the balance to abundant supply, and even oversupply in some regions. Influenced by the simultaneously slowing down of the power demands in both supplier and receiver sides, provinces sending out large amounts of electricity meet more difficulties for electricity overcapacity.

Second, the rapid development of renewable energy, along with the launching of a large number of self-generation power plants, is compressing the space for traditional coal-fired power plants. During the period of the 12th Five-Year, great achievements have been made for China’s wind and solar power generation, of which the installed capacity and power generation increase rapidly year by year. With the rapid growth of renewable energy and expansion of the self-owned power plant, the development space of coal-fired power plants has also been compressed.

Third, the low prices of coal caused overinvestment in coal-fired power plants. Influenced by continuously declining prices of coal, investment in coal-fired power plants has increased dramatically by 23.4% in 2014, which kept growing in 2015 and 2016 at annual rate of 1.6% and 0.9%, respectively. Decreasing coal prices brought high profit expectations and lead to a continuous high-level investment. Considering the construction cycle, some newly-established coal-fired power plants would be put into operation in the next few years, which would exacerbate the pressure of overcapacity.

Fourth, planning of coal-fired power was not timely updated either well regulated, leading to poor development guidance. Considering the changing background of slowing power demand, fast development of new energy, introduction of the national main functional areas planning and so on, the coal-fired power generation planning has not been timely updated or adjusted. For example, "Strategic Action Plan for Energy Development (2014-2020)" by State Council has planned 9 coal-fired power generation bases, while "Research Report of 12th Five-Year Plan for Power Industry" by China Electricity Council has planned 16 large coal-fired power generation bases. Absence of coordination among different plans as well as effective implementation, lost constraint for the constructions of coal-fired power plants.

Fifth, the approval authority decentralization loosed constraints for local coal-fired power generation growth. Since coal-fired power plants are mainly state-owned and market mechanism is far away from perfect, these coal-fired power plants or investors are not so sensitive to the supply and demand of the market. At the end of 2014, the State Council decentralized the approval authority for thermal power projects to the provincial governments. Stimulated by the promotion of economic growth, the increment of employment, and the initial reinforcement of the self-sufficiency of energy and power, local governments have led a rapid growth in coal-fired power generation. Fast growing coal-fired power capacity in the eastern provinces (traditional power receivers) reduced willingness to accept power from other provinces, which worsen the overcapacity of power supplying provinces.

**Analysis of Coal-fired Power Capacity Needed by 2030 without Consideration of Drop-off Cost**

With the development of clean energy, the declining trend of the utilization hours of the coal-fired units would continue. The role of coal-fired power in China would gradually vary from the dominant energy provider to auxiliary power supplier and flexible peak shaving supplier. Based on the forecasts of energy balance, power balance and flexible peak demand, the reasonable capacity of coal-fired power in China would be 980 GW in 2020 without considering the drop-off cost.

From the perspective of energy balance. Assume that (1) China's electricity demand in 2020 is 6.8-7.2 trillion kWh; (2) renewable energy power capacity, nuclear and gas-fired power capacity is determined by the planning objectives in the "13th Five-Year Plan of Electric Power Industry" (hereinafter referred to as "Plan")[4]; (3) the utilization hours are determined by the wind and
photovoltaic power protectively purchased hours published in 2016 and the actual operating situations in recent years; (4) the power reserve of 0.2 trillion kWh. Thus, the electricity demand of coal-fired power would be about 4.5-4.9 trillion kWh. Assuming that 5000 hours would be utilized, corresponding coal-fired power capacity would be 0.9-0.98 TW.

From the perspective of power balance. Assume that (1) the maximum power demand in 2020 is 1.15-1.21 TW; (2) installed capacity of hydro (including pump storage), wind, solar, nuclear, gas-fired power generation is also determined by the above-mentioned Plan; (3) 10% confidence coefficient of the wind and solar power capacity is selected; (4) system reserve rate is 20%. Thus, the calculated installed capacity of the coal-fired power would be about 0.8-0.87 TW. Even in the conservative scenario, which assumes that the solar power would not participate in the peak load power balance and the system reserve rate is 25%, the demand for coal-fired power capacity would be about 0.87-0.94 TW.

From the perspective of flexible peak shaving. By 2020, the demand of peak shaving for wind and solar electricity generation would be about 0.267 TW, while the demand of peak shaving for load fluctuation would be about 0.288-0.303 TW. On the basis of the most conservative estimation, which makes an assumption of the complete anti-peak regulations of the wind and solar power, the requirement of system’s total peak load regulating capacity would be 0.555-0.570 TW. Considering (1) the capacity objectives for the pumping storage (40 GW) and the gas-fired power capacity (110 GW) proposed in the “Plan”; (2) the demand response capacity of 35 GW; (3) the storage capacity of 20 GW, the above-mentioned flexible power sources would be 0.205 TW in total, and the need for coal-fired power would be 0.350-0.365 TW. Estimating that the average depth of peak shaving would be 50%, then the capacity demand for coal-fired power would be 0.70-0.73 TW.

In 2016, China’s installed capacity of coal-fired power was 0.94 TW, approaching the coal-fired power capacity demand by 2020. In the case that no coal-fired power plants would be newly authorized, the approved projects might lead a surplus of 0.22 TW with an excess rate of 22.4% for coal-fired power generation by 2020. In contrast, if the projects that have been approved but are not yet started would be halted, the national surplus of coal-fired power would be 0.16 TW with an excess rate of 16.3%.

Taking into account China’s electricity demand of 10.4 trillion kWh in 2030, China’s peak demand for the coal-fired electricity would be about 1.15TW, which would be reached around 2025. In consideration of China’s commitment of reaching the carbon emission peak around 2030, along with the basic judgments of the slowing down electricity demand growth as well as the increasing competitive of new energy power generation technologies, the coal-fired power capacity would continuously decline after having reached the peak. Thus, the 1.15 TW coal-fired power capacity would become a historic peak.

Analysis of Coal-fired Power Capacity Needed by 2050 Based on the System Optimization Methodology

This system optimization model is composed of two parts. First one is the Multi-regional Power System Planning Model (MPSPM) considering the coordinate development of the power generation-grid-load-storage. It makes power demand and power supply potential of each region the inputs, makes clean energy development targets and power balance the basic constraints, and optimizes the national power supply structure, layout and power flow by least total cost. Electric power demand is forecasted to be 7.0 TWh in 2020, 9.1 TWh in 2030, 10.5 TWh in 2040, and 11.6 TWh in 2050. Maximum load is forecasted to be 2.06 billion kW by 2050. The model program consists of more than 7,000 formulas, about 35,000 exogenous variables, and about 5000 endogenous variables. Parameters are from published policies [5] and existing research finished by State Grid Energy Research Institute.

Second one is the Multi-regional Power Production Simulation Model (MPPSM) considering the coordinate development of the power generation-grid-load-storage. Based on the output of MPSPM
mentions above, MPPSM could achieve two functions. One is to verify the results from MPSPM to make sure it’s practical. The other one is to show the operation mode of future power system. It can be used to solve the optimal results of power supply, transmission capacity, regional demand response and energy storage of typical days. The model program consists of more than 36,000 formulas, about 158,000 exogenous variables, and about 32,000 endogenous variables.

Results [6] show that coal-fired power will still play an important role in the power system by 2050. As the wind power, photovoltaic and other renewable energies are random and volatile, it is difficult for the power system to ensure the power balance. Together with the off-grid possibility and other features unfriendly to the system, it could say that wind and other renewable electricity is difficult to support the safe and stable operation of the power system. Therefore, the future power system needs coal-fired units to play the role of peak shaving and standby resource. According to the results, coal-fired power capacity will be 1120 GW by 2030 and decrease to 690 GW by 2050. However, with the role of coal-fired units change, its utilization hours will gradually decline, which makes coal-fired power generation decline faster after 2030. It means from the perspective of power generation, coal-fired power will accelerate its drop-off after 2030.

By 2050, coal-fired power generation will account for 14% of the total power generation. Gas-fired power is not competitive due to the cost constraints. From the point of peak shaving, the large scale of coal-fired power has huge potential if the mechanism runs smoothly. Non-fossil power generation will account for around 80% of the total generations.

Compared with the results not considering the system cost, coal-fired power capacity here is somewhat larger because of the price advantage. The peak capacity of coal-fired power will reach 1149 GW in 2026, and its power generation will reach the peak in 2025 since of decreasing utilization hours. And from the perspective of power generation, coal-fired power will accelerate its drop-off after 2030.
Conclusions and Countermeasures

Coal-fired power in China is gradually changing its role in the power sector from the dominant energy provider to auxiliary power supplier and flexible peak shaving supplier. Existing coal-fired power capacity is almost enough to meet the electric power demand in future. While if we consider the system cost, there is still some space for its development. The peak capacity of coal-fired power will reach 1149 GW in 2026, and its power generation will reach the peak in 2025 since of decreasing utilization hours. Coal-fired power will accelerate its drop-off after 2030. By the year 2050, coal-fired power capacity will decrease to 690 GW, and its generation will account for 14% of the total power generation.

However, we still need to take urgent measures to control the rapid construction of coal-fired power units which happened in the last few years, to keep it in a rational pace and avoid serious overcapacity. There are various measures could be adopted to curb the further accumulation of the risks of coal-fired power overcapacity and to orderly alleviate the existing capacity. The beneficial factors of China’s supply-side structural reform, the power system reform, and the state-owned enterprise reform should be adequately utilized. With regard to the short-term, the strict control of the new established capacity as well as the resolution of the stock production should be mainly focused. In long-term, the goal of market improvement should be set, while the systematical dispersal of the coal-fired power overcapacity should be proceeded. Thus, the stable and healthy development of the industry of coal-fired power could be ensured.

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References