Influence Analysis of Different Capacity Reduction Policies in Annual Power Generation Planning under Electricity System Reform in China

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Abstract. In China, the new round of electricity market reform requires power generation to change from traditional planned power generation management into market-driven contract power generation. In the transition period, the remaining power generation plan management bears with tasks of guaranteeing power grid safety and stable operation and balancing supply and demand under the impact of electricity market uncertainty. Capacity reduction is an important policy means in plan management to inhibit power plants’ vicious competition and help the electricity market steadily development. This paper researches different capacity reduction mode of the electricity market reform pilots, compare and analysis the influence of the capacity reduction modes by modeling and simulating, and proposes some suggestion for capacity reduction management in annual planning during the electricity reform transition period.

1. Introduction

Before the power system reform, the State Grid and the China Southern Power Grid as well as some local wholesale power grid provide electricity for multiple customers. From 2002 Power System Reform Program (Document No.5), power plants and grid separated into independent units. But the electricity market had not been built after that reform. Annual power generation plan is made by the corresponding grid company planning department and the scheduling department adjusts it according to the actual operation power balance constraints. Therefore, before the new round of power system reform, which started in 2015, power generation volume of each power plant is still decided by the power grid mainly in the form of power generation plan.

Power generation plan is an important link in grid dispatch and operation management, reasonable power generation plan can maximize the use of grid resources and ensure the safety and economical operation of the power grid [1]. Different cycles of power generation plans have different characteristics. Short-term power generation, namely day-ahead plan and real-time plan, depends on the short-term system forecast and scheduling and with high accuracy [2]-[4]. Long-term (annual) power generation plan is the basic of electricity supply and demand balance and electricity trading between the power grid and power plants. Medium-term (monthly) power generation plan is the connection link between the long-term and short-term plan. Under the management mode that the power grid unified purchase and sale electricity, the full cycle unit combination state and the unit load
rate is the basis of coordination and optimization coordination and optimization. By coordinating different time series power generation plans, the convergence and association among different cycle power generation plan is achieved [5]-[8].

The release of the Document NO.9 (Some Opinions on Further Deepening the Reform of Electric Power System) put forward the reform objectives of carrying out effective competition in both power generation side and the sale side, cultivating independent market players, and build a power trading pattern with diversified body and orderly competition. Then the release of a series of supporting documents not only influenced the interest pattern in the sale side, but also breaking the original power generation plan management cycle, as well as proposed new requirements for the power grid to adjust their plan management mode to fit the new development situation. The trading objects of power plant changes from the power grid and local government into terminal customers and independent sales company. The former trading object pursues power grid safety and stable operation, local power plants economic balance and social sustainable development. The latter trading object mainly pursues its own access to high quality safe and reliable power supply. The change of trading object’s demand and the oversupply relationship make the power plants show the trend of polarization. The utilization hours of efficient units would increase rapidly, along with a substantial increase in profits. Small, old or inefficient units, lacking of market competitiveness, would face with great economic losses or directly out of the market. In the transition period of the traditional planning mode into the market mode, maintaining the basic stability of the power industry is very important. Especially in the early period of building electricity market, vicious bidding, interest conflict among power plant, customer and the power grid world hinder the orderly electricity market development and bring uncertainty for power supply and demand balance.

Currently, the reform pilots are avoiding the above problems by controlling the released power generation volume, namely market trading cap. For example, in the Beijing - Tianjin - Tangshan regional power grid the market trading cap is 20% of the local electricity consumption in 2016 and the actually implementation ratio is less than 10% at the end of the year. The market process requires the market trading cap increase, except release the power generation volume step by step, plan capacity reduction is another effective measure to adjust different power plants’ interest distribution and maintain the basic stability in the power generation side.

The concept of capacity is proposed in the management of large-customer and power plant directly trading. In November 2009, the National Electricity Regulatory Commission published the document of "Power customer and power plan directly trading pilot basic rules (Trial)" [9], which stipulates the power plants which obtained direct trade qualification should reduce their capacity in annual plan according to their contract power volume, and the corresponding dispatch organization would not allocate power plan to this part of capacity. However, this rule has not been implemented nationwide. Some provinces cancelled the capacity reduction or replaced it with different generation power reward rules [10]. Reduce or not reduce the corresponding capacity makes big difference on the allocated power generation volume in annual plan of each power plant directly and influence market supply and demand relationship indirectly. Unreasonable capacity reduction mode may bring arbitrariness and chaos into local power system reform and hinder power industry orderly development. Currently, the attitudes and measures of the electric reform pilots on this point are not the same. This paper combings different capacity reduction mode in the power reform transition period and compare the influences of capacity reduction on power plant, customer and the power grid by building annual planning model and benefit analysis mode.

2. Market first and plan First Management Mode

As of the end of August 2016, there are 15 electric power system reform comprehensive pilots, 18 transmission and distribution price pilots and 5 sales-side reform pilots all around the country. Electric generation plan release is the foundation of pilot operation. Therefore, actually every pilot is facing the problem of plan reduction problem. But they took different measures on it, which can be divided into market first and plan first management modes.
2.1. Market First Management Mode
In market first management mode, the power generation plan steps are drawn in Fig. 1:

- Partial power is preempted for market transactions;
- Plan reduction according to the market trading power;
- Calculate renewable and heating power as the guaranteed power generation, then deduct the guaranteed power generation from the remaining planned electricity.
- Assign the remaining planned electricity to each unit according to the principles of power generation planning, and in accordance with the reward and punishment mechanism, the unit maintenance arrangements to adjust the unit hours of power generation.

2.2. Plan First Management Mode
In plan first management mode, the power generation plan steps are drawn in Fig. 2:

- Calculate the necessary power generation hours of each unit according to the government policies, inter-provincial tie line transaction, wind power, solar photovoltaic power generation as well as heating power.
- Limit the market transaction permitting capacity of the units that participated in annual planning according to their allocated power generation hours.
The remaining power generation, namely the total demand minus the planned power, is placed in the market for competition. For the current Chinese electricity market, the market first management is more suitable, from the aspect of power grid security, power balance and the acceptance of the parties. Therefore, this paper discusses the different reduction policies under the market first management mode.

3. Different Plan Reduction Policies

Under the market first management mode, the transaction results would influence annual plan, which reflects as plan reduction. Because thermal units with big installed capacity are generally more efficient than that with small installed capacity, the plan allocation is made according to the effective capacity level of each unit, which is called differential generation hour (1).

\[ T^\text{PLAN}_i = f_i(C^\text{PLAN}_i) \]  

where in \( T^\text{PLAN}_i \) is the allocated power generation hour of unit \( i \). \( C^\text{PLAN}_i \) is the effective capacity of unit \( i \) that participate into power generation plan. \( f_i() \) is the calculation function to get the allocated power generation hour of unit \( i \) according to its effective capacity.

According to the actual planning principle units are differentiated into different level, and the allocated hour is determined the capacity level of each unit. A level would be chose as the basic level and other levels cloud calculate their power generation hour based on the allocated power generation hour of the basic level. Then (1) could be detailed as (2):

\[
T^\text{PLAN} = \begin{cases} 
\text{INT} \left( \frac{C^\text{PLAN}_i - C_0}{\Delta C} \right) - 1 \times \Delta T + T_0, & C^\text{PLAN}_i \leq C_0 \\
\text{INT} \left( \frac{C^\text{PLAN}_i - C_0}{\Delta C} \right) \times \Delta T + T_0, & C^\text{PLAN}_i > C_0 
\end{cases}
\]  

where in \( T_0 \) is the allocated power generation hour of the basic level units, which is calculated by supply and demand balance. \( \Delta T \) is the hour difference between two adjacent levels. \( \Delta C \) is the level step of power generation capacity.

Different plan reduction method makes different influence on. As introduced in chapter 1, market transaction result would influence the effective capacity in plan. And may also be influence by other units in the same area, total power generation volume and total market transaction power volume and so on. The relationship between the effective capacity in plan and the factors could be expressed as (3).

\[ C^\text{PLAN}_i = f_i\left( C_i, Q^\text{MARKET}_i, Q^\text{MARKET}, C^\text{MARKET} \right) \]

where in \( f_i() \) is the calculation function that determined by local policy. is the installed capacity of unit \( i \). \( Q^\text{MARKET}_i \) is the market transaction volume of unit \( i \). \( Q^\text{MARKET} \) is the total market transaction volume \( C^\text{MARKET} \) is the total installed capacity of the units that participated into market.

According to different plan reduction policies, (3) would be different in different areas. Therefore, (3) is one of the core point in this model, this paper would detail equation in chapter IV. And the following of this chapter introduces the calculation of \( T_0 \) in (2) to complete the annual planning method. The value of \( T_0 \) is determined by power supply and demand balance.

Recent years, to response to the energy-saving policies, encourage renewable energy development, and encourage power generation units stable output, many of the plan management departments have already given priority to renewable power units like wind power and nuclear power, peak-valley...
shifting units like pumped storage power station. And reserve some power plan for reward and punish. Therefore, the annual plan could be divide as (4):

\[ Q^{TOTAL} = Q^{RENEWABLE} + Q^{RESERVE} + Q^{PLAN} + Q^{MARKET} \]  

where in \( Q^{TOTAL} \) is the total power generation volume that the plan management department used for allocates. \( Q^{RENEWABLE} \) is the total protected acquisition of renewable energy, which is determined to the protected power generation hour of the corresponding resource area and the actual power generation capacity. \( Q^{RESERVE} \) is the reserved power plan determined by the plan management department according to the historical data. \( Q^{PLAN} \) is the total power plan for other units that dispatched by the State Grid and not have the priority.

In (4) and would be forecasted before annual planning and market transaction would finish at the end of last year. Then \( Q^{TOTAL} \), \( Q^{RENEWABLE} \), \( Q^{RESERVE} \) and \( Q^{MARKET} \) could be regard as constant, and \( Q^{PLAN} \) could be calculated. The relationship between \( Q^{PLAN} \) and \( T^{PLAN} \) is:

\[ Q^{PLAN} = \sum_{i=1}^{I} T^{PLAN}_i \times C^{PLAN}_i \]  

where in \( I \) is the number of the units to allocate plan.

There are three main kinds of measures on plan reduction, namely, the same proportion reduction (SPR) method, hours by user reduction (HUR) method and coefficient reduction (CR) method. The SPR method means the capacity of all the power generation units that participated into the market would be reduced with the same proportion. The reduction production is determined by total trading electric volume, market equivalent utilization and total capacity of the power generation units that participated into the market. The HUR method means the plan reduction degree varies with the trading electric volume and the customer equivalent utilization hour last year of each power generation enterprise. The CR method means the capacity would be reduced according to the trading electric volume and the given coefficient, with is determined by the local government.

In SPR method a hypothetical parameter is defined, which is called market equivalent, as (6):

\[ C^{MARKET} = \frac{Q^{MARKET}}{T^{MARKET}} \]  

where in \( T^{MARKET} \) is the market equation hour, which is determined by local government according to the historical data, for example in 2016 the Shandong province set it to be 6000h.

All the units that participated into market would reduce their effective capacity with the same proportion. The proportion is calculated by (7):

\[ p^{SPR} = \frac{C^{MARKET}}{\sum_{i=1}^{I} C_i} \]  

Then in this method (3) in chapter changes into:
In HUR method customers’ utilization hour is the main factor that influences $C_{PLAN}^i$. Assume unit $i$ reached deal with $J$ customers. The definition of customer $j$’s utilization hour is:

$$T_j = \frac{Q_j}{C_j^{max}}$$

where in $Q_j$ is the total power consumption volume last year of customer $j$. $C_j^{max}$ is the max demand capacity last year of customer $j$.

Unit $i$ should reduce its effective capacity in plan considering all the transactions among $J$ customers:

$$\Delta C_j = \sum_{j=1}^{J} \frac{Q_{ij}^{MARKET}}{T_j \times \gamma}$$

where in $Q_{ij}^{MARKET}$ is the transaction power volume between unit $i$ and customer $j$. $\gamma$ is an adjustment coefficient that determined by government to adjust the reduction degree, for example in 2016 the Sichuan province set it to be 2.

Then in this method (3) changes into:

$$C_{PLAN}^i = C_i - \Delta C_i = C_i - \sum_{j=1}^{J} \frac{Q_{ij}^{MARKET}}{Q_j^{max}} \times \gamma$$

In CR method plan reduction only influenced by policy and themselves market transaction volume and last year power generation hour.

$$\Delta C_j = \frac{Q_{j}^{MARKET}}{T_j^{last}} \times \mu$$

where in $T_j^{last}$ is the power generation hour of unit $i$ in the last year. $\mu$ is the capacity reduction coefficient and $\mu \in [0,1]$, which is determined by local policy, for example in 2016 the Beijing, Tianjin and North Hebei area set it to be 0.5.

Then in this method (3) changes into:

$$C_{PLAN}^i = C_i - \Delta C_i = C_i - \frac{Q_{j}^{MARKET}}{T_j^{last}} \times \mu$$

4. Multi-stakeholder benefit Analysis

The electric power system reform directly changes the benefit of the power grid, power user and power unit. According to the above model different capacity reduction policy would make differences on the annual plan. This chapter builds benefit analysis modes for power user, power unit and the power grid to analysis the influence of different capacity reduction policy on those stakeholders.

4.1. Benefit Analysis of Power User
Benefit change of power user mainly reflected in electricity purchase change, which can be described as:

$$
\Delta \pi^{new} = (Q^0 - Q^*) \cdot p_b - \sum_{i=1}^{I} Q^i \cdot (p^i + p^{new}) - (Q^0 - Q^*) \cdot p_b
$$

$$
Q^* = (Q^0 - Q^*) \cdot \left[1 - (1 - \eta_l) \cdot (1 - \eta_p) \right]
$$

where in $p^{trans}$ is the average transmission and distribution price. $Q^0$ and $Q^*$ are the loss power before and after the power system reform, respectively. $\eta_l$ and $\eta_p$ are the average line loss and plant power consumption rate in the corresponding area, respectively. $p_b$ is the average catalog price.

### 4.2 Benefit Analysis of Power Unit

Before the power system reform, the interest of power unit is entirely up to the plan, which can be calculated by:

$$
\pi^i_0 = R^i_0 - O^i_0 = Q^i_0 \times \left( p^i - o_i \right)
$$

where in $p^i$ is the on-grid tariff of unit $i$. $Q^i_0$ is the total power generation volume of unit $i$. $o_i$ is the average power generation cost per kwh.

When part of the planned electricity released into the market the interest of power unit changes to be:

$$
\pi^i_1 = R^i_1 - O^i_1 = Q^i_1 \times p^\text{m} + Q^i_0 \times p^i - (Q^i_0 + Q^i_1) \times o_i
$$

where in $Q^i_1$ is the market trading power of unit $i$. $p^\text{m}$ is the average market trading price of unit $i$.

Then benefit change of unit $i$ is:

$$
\Delta \pi_i = \pi^i_0 - \pi^i_1
$$

$$
= Q^i_1 \times (p^\text{m} - o_i) + (Q^i_1 - Q^i_0) \times (p^i - o_i)
$$

### 5. Case Study

#### 5.1 Basic Data

![Power plant unit number and capacity distribution](image)

Figure 3. Power plant unit number and capacity distribution.
This paper chooses a regional power grid as the study subject, which contains three provinces and cities, namely A, B and C. The total power generation volume is allocated to 60 power plants by annual plan and market competition. According to the unit number and average capacity, power plants in this regional power grid were classified into different types, as drawn in Fig. 3. In A province, the units are mainly small capacity units with 30 million kW or less installed capacity. Power plants in B province and C are mainly large and medium-sized units, especially C province has some big capacity units with 100 kW or more installed capacity. Other units in Fig. 3 means the power plants are not built in A, B or C province, but still provide power to this area. On this basis, this paper chooses three power plants as typical subjects to analysis, with 30 million kW, 60 million kW and 100 million kW capacities. Parameters of the three plants are list in Table I. Line loss and plant electricity rate are respectively 6% and 8% in this area.

Table 1. Parameters of the Typical Power Plants

| Power Plant | Average capacity (million kW) | Unit coal consumption (g/kwh) | Unit cost (Yuan/kwh) | Unit number |
|-------------|-------------------------------|-------------------------------|---------------------|-------------|
| #1          | 100                           | 362.33                        | 0.126816            | 2           |
| #2          | 60                            | 454.16                        | 0.158956            | 4           |
| #3          | 30                            | 602.43                        | 0.210851            | 2           |

The annual transaction is mainly for power generation companies and power companies or electricity users signed a bilateral agreement. The transaction volume and piece are influenced by both power generation company and power purchase decisions, which are difficult to predict without long-term historical data. Until now this area does not have meaningful market transaction reference data. Therefore, this paper assumes low-cost units priority access to electricity trading because of its stronger competitiveness, and simulate market trading result. This paper simulates the plan release degree, capacity reduction coefficient and market equivalent hour, and sets the different scenarios as Table II. Respectively under 10% and 30% plan release ration, analysis capacity reduction result and multi-stakeholder benefit with different capacity reduction coefficients and market equivalent hours. Accessibility of power plants to participate into the market and transaction limit are set according to local policy.

Table 2. Parameters in Different Scenario

| Plan release ratio | 10% | 30% |
|--------------------|-----|-----|
| Capacity reduction coefficients and market equivalent hours in different scenario | Scenario 1: \( \mu=0 \) | Scenario 4: \( \mu=0 \) |
| | Scenario 2: \( \mu=0.5 \) | Scenario 5: \( \mu=0.5 \) |
| | Scenario 3: \( \mu=1 \) | Scenario 6: \( \mu=1 \) |
| | Scenario 7: \( T_m=5000h \) | Scenario 9: \( T_m=5000h \) |
| | Scenario 8: \( T_m=6000h \) | Scenario 10: \( T_m=6000h \) |

5.2. Result and Analysis

1) Power plant benefit analysis

Changes of the three power plants power generation volume in scenario 1~6 and 7~10 are list in Table III and Table IV, respectively. The percentage value in Table IV means proportion of power generation volume in different scenarios to the allocated power generation volume before the power system reform. According to Table III and Table IV, power generation volume change trends of the three power plants are different with different plan release ratios and different capacity reduction coefficients, while the change trends reflect certain regularity with different market equivalent hours.
the plan allocated power generation volume. With the increase of plan release proportion, the total power generation volumes of power plant #1 are more than the original allocated power generation volume. The obtained power generation volume from market trading is less than the reduced planed power generation volume.

Power plant 2# has medium capacity and when the plan release proportion is small (scenario 1, scenario 2 and scenario 3), power generation cost of power plant #2 is more than the power plants with large-capacity units. Therefore, whether the capacity reduction coefficient is big or small, power plant #2 is hard to get power generation volume in the market, and its total power generation volume is always less than the original allocated power generation volume. With the increase of plan release proportion, the power plants with large-capacity comes to their market trading upper limit, the remaining market share would be obtained by the power plants with medium power generation cost.

When the capacity reduction coefficient is small, the total power generation volumes of power plant #2 are more than the original allocated power generation volume (scenario 4 and scenario 5). On the opposite, when the capacity reduction coefficient is big, the plan allocated power generation volume would be greatly reduced and the total power generation volumes of power plant #2 are less than the original allocated power generation volume.

Power plant #3 represents the power plants with high power generation costs, which makes them lack of market competitiveness and hard to obtain market power generation volume. In the above situations, the total power generation volumes of power plant #3 are less than the original allocated power generation volume. With the increases of the capacity reduction coefficient, this type can hardly get market trading that their plan allocated power generation volumes almost do not influence by the capacity reduction coefficient. Because of power plants with large ore medium capacity would get less plan-allocated power generation volume, the plan allocated power generation volume of power plant #3 increased (scenario 4, scenario 5 and scenario 6).

Table 3. Changes of the Three Power Plant Power Generation Volume in Coefficient Reduction Mode

| Power plant | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 |
|-------------|------------|------------|------------|------------|------------|------------|
|             | plan       | market     | total      | plan       | market     | total      |
| #1          | 68.3%      | 94.7%      | 163.5%     | 36.6%      | 94.7%      | 131.4%     |
| #2          | 65.1%      | 36.4%      | 101.5%     | 53.9%      | 36.4%      | 90.3%      |
| #3          | 77.2%      | 0.0%       | 77.2%      | 78.1%      | 0.0%       | 78.1%      |
|             |            |            |            |            |            |            |
|             | 44.0%      | 94.7%      | 138.7%     | 24.0%      | 94.7%      | 118.7%     |
| #2          | 41.6%      | 94.7%      | 136.3%     | 22.7%      | 94.7%      | 117.4%     |
| #3          | 49.4%      | 0.0%       | 49.4%      | 51.1%      | 0.0%       | 51.1%      |

According to Table III, power plant #1 has the maximum average capacity and minimal power generation cost. Therefore, in the cost-oriented electricity market power plant #1 can obtain more market share than power plant 2 and 3. In scenario 1, 2, 4 and 5, if the capacity reduction coefficient is small, the total power generation volumes of power plant #1 are more than the allocated power generation volume before the power system reform. But when the capacity reduction coefficient is big (in scenario 3 and scenario 6), the total power generation volumes of power plant #1 are less than the original allocated power generation volume. The obtained power generation volume from market trading is less than the reduced planed power generation volume.

Power plant #3 has medium power generation cost of power plant #2 is more than the power plants with large-capacity units. Therefore, whether the capacity reduction coefficient is big or small, power plant #2 is hard to get power generation volume in the market, and its total power generation volume is always less than the original allocated power generation volume. With the increase of plan release proportion, the power plants with large-capacity comes to their market trading upper limit, the remaining market share would be obtained by the power plants with medium power generation cost.

When the capacity reduction coefficient is small, the total power generation volumes of power plant #2 are more than the original allocated power generation volume (scenario 4 and scenario 5). On the opposite, when the capacity reduction coefficient is big, the plan allocated power generation volume would be greatly reduced and the total power generation volumes of power plant #2 are less than the original allocated power generation volume.

Power plant #3 represents the power plants with high power generation costs, which makes them lack of market competitiveness and hard to obtain market power generation volume. In the above situations, the total power generation volumes of power plant #3 are less than the original allocated power generation volume. With the increases of the capacity reduction coefficient, this type can hardly get market trading that their plan allocated power generation volumes almost do not influence by the capacity reduction coefficient. Because of power plants with large ore medium capacity would get less plan-allocated power generation volume, the plan allocated power generation volume of power plant #3 increased (scenario 4, scenario 5 and scenario 6).

Table 4. Changes of the Three Power Plant Power Generation Volume in the Same Proportion Reduction Mode

| Power plant | Scenario 7 | Scenario 8 | Scenario 9 | Scenario 10 |
|-------------|------------|------------|------------|-------------|
|             | plan       | market     | total      | plan        | market     | total      |
| #1          | 9.5%       | 160.0%     | 169.5%     | 7.9%        | 160.0%     | 167.9%     |
| #2          | 5.6%       | 38.1%      | 43.7%      | 4.7%        | 38.1%      | 42.8%      |
| #3          | 45.2%      | 0.0%       | 45.2%      | 45.2%       | 0.0%       | 45.2%      |
|             | 18.9%      | 156.3%     | 175.3%     | 15.7%       | 160.0%     | 175.7%     |
| #2          | 11.1%      | 99.2%      | 110.3%     | 9.2%        | 99.2%      | 108.5%     |
| #3          | 29.9%      | 0.0%       | 29.9%      | 29.9%       | 0.0%       | 29.9%      |
According to Table IV, power plant #1 has the advantage of low power generation costs. Although the plan allocated power generation volumes significantly reduced in different scenarios, the total power generation volumes are more than the original allocated power generation volume. And with the increases of plan release proportion, the total power generation volume increases. The bigger the market equivalent utilization hour the more plan allocated power generation volume and the more total power generation volume.

Power plant #2, with the increases of plan release proportion, power plants with big capacity reaches their market trading upper limit. Power plants like power plant #2 can obtain the remaining market share and their total power generation volume increases. And the bigger the market equivalent utilization hour the more the deducted planned capacity and the less plan allocated power generation volume.

Power plant #3 has high power generation costs that hard to obtain market share and dose not influence by the market equivalent hour. Therefore, the total power generation volume decreases with the increasing plan release proportion.

Assuming the market-clearing price is 5% less than the benchmark price, calculate and compare the interest of the three power plants in different scenarios, as drawn in Fig. 4. Power plant #1, with big capacity and low power generation costs, gets a large growth of interest in different scenarios. Only in scenario 3 and scenario 6 the total profit is small because of the big capacity reduction coefficient makes its plan allocated power generation volume significantly reduced. The interest of power plant #3 decreases with the plan release proportion increases because it is hard to obtain market share. And influenced by other plants’ plan allocated power generation volume, when capacity reduction coefficient is big or market equivalent hour is small, its profit decrease extent would be less. Power plant #2 is influenced obviously by both plan release proportion and capacity reduction mode. When the plan release proportion is big while capacity reduction coefficient is small, its profit is more than the original profit before the power system reform. And under the same proportion reduction or big capacity reduction coefficient management mode, the profit is always less than the original profit before the power system reform.

**Figure 4.** The profit change of the three power plants in different scenarios.

2) Customer benefit analysis

Considering the actual market transactions and related policies, this paper assumes the average transaction price is ±5% (0.38 Yuan/kWh and 0.42 Yuan/kWh), more or less than the average transmission and distribution price is 0.2 Yuan/kWh and the average catalog price is 0.6 Yuan/kWh (large industrial customers). Customer benefit change with different plan release proportion is drawn in Fig. 4. On the one hand, the trading reference base is the benchmark price, which is obviously less than catalog price on customer side. The difference between the trading price and the benchmark price is more than the transmission and distribution price. When the trading price is 5% less than the benchmark price, customer benefit increased significantly. When the trading price is 5% more than the benchmark price, customer benefit decreased slightly because of the different between the benchmark.
price and the catalog price are close to the transmission and distribution price. On the other hand, according to Fig. 5, customer total benefit is not directly related with the corresponding capacity reduction management mode. The capacity reduction mode would influence power plant decision making. Therefore, the capacity reduction mode would affect the relationship between supply and demand and the trading piece to an extent. In this way the capacity reduction mode influences customer individual customer’s benefit obviously. For example, power plants like power plant #1 would change their decision under different plan release proportion. On the one hand, they may reduce market trading power generation volume to increase planed capacity, plan allocated power generation volume and total profit. On the other hand, they may increase their trading prices on the basic of obtain enough market shares.

![Figure 5. Customer benefit change under different plan release proportion.](image)

6. Conclusions
This paper sorted out different capacity reduction mode in plan management during the transitional stage of the power system reform. According to the specific provisions of different provinces (cities) and pilots, put forward three capacity reduction modes and their corresponding models as well as the basic power generation hour calculation model in annual planning. The case study compared and analyzed the benefit changes of power plant, power customer and the power grid, the conclusions are as follows:

- This bigger the plan released proportion, the greater the advantage of plants with big capacity and low power generation costs, and the greater the disadvantage of the plants with small capacity and high power generation costs. But the profits of those plants do not show a positive/negative proportion or positive/negative correlation between with the plan release proportion. Their profit is mainly influenced by three functions, namely, the plan release proportion, the capacity reduction mode and their own decision making.
- Customer total benefit change rate increases with the increase of plan release proportion. It is not directly influenced by capacity reduction mode, but still indirectly influenced by the capacity reduction mode. The capacity reduction mode influences power plant decision making and supply and demand relationship, customer total benefit and individual customer benefit would be influenced by the capacity reduction mode.

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