Study on economy of flue gas ultra-low emission in coal-fired power

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Abstract. Along with the rapid progress of flue gas ultra-low emission reconstruction in coal-fired power plants in recent years, flue gas pollutant control is markedly improved. However, it also leads to the increase of energy consumption and material consumption of environmental protection facilities\textsuperscript{1}, such as power consumption, desulfurization absorbent, DeNOx reductant, SCR catalyst replacement, etc. Consequently, the direct or indirect operating costs of environmental protection facilities have increased significantly\textsuperscript{2}. In addition, since the second half of 2016, the raw materials (limestone, liquid ammonia) and transportation costs of environmental protection facilities have shown a trend of substantial increase. Coupled with the reduction of unit utilization hours and the continuous increase of coal price, the per-unit power generation cost have been increased, which brought greater pressure to the operation of power generation enterprises.

1. Introduction
Along with the rapid progress of flue gas ultra-low emission reconstruction in coal-fired power plants in recent years, flue gas pollutant control is markedly improved. However, it also leads to the increase of energy consumption and material consumption of environmental protection facilities\textsuperscript{1}, such as power consumption, desulfurization absorbent, DeNOx reductant, SCR catalyst replacement, etc. Consequently, the direct or indirect operating costs of environmental protection facilities have increased significantly\textsuperscript{2}. In addition, since the second half of 2016, the raw materials (limestone, liquid ammonia) and transportation costs of environmental protection facilities have shown a trend of substantial increase. Coupled with the reduction of unit utilization hours and the continuous increase of coal price, the per-unit power generation cost have been increased, which brought greater pressure to the operation of power generation enterprises.

Given the present situation of flue gas ultra-low emission in coal-fired power plants, several typical problems about economic efficiency have been analyzed and discussed, including coordinated optimization operation, emissions target control, energy efficiency management on the basis of extensive and thorough investigations. Relevant guidance and countermeasures are proposed to provide further reference for subsequent operation and maintenance of power generation enterprises.

2. Optimizing operation
The flue gas treatment system of coal-fired power plants mainly includes three parts: DeNOx, dust remover and desulfurization. They are connected in series in the flue gas system, with each section containing one or more devices. After the transformation of ultra-low emission, the equipment
components become more complex and the mutual influence between the equipment is further increased. However, due to historical reasons, current environmental protection facilities are generally independent and lack of unity and coordination in construction and operation management, which fails to give full play to the synergistic effect of environmental protection facilities and leads to poor economic efficiency.

Taking DeNOx facilities as an example, low-NOx combustion and SCR flue gas DeNOx are the most widely used DeNOx technologies in coal-fired power plants at present, and most power plants combined the two DeNOx technologies. From the angle of the economic efficiency, low-NOx combustion have no direct operation cost. Decreasing SCR DeNOx inlet NOx concentration through low-NOx combustion can effectively reduce the pressure and cost of the follow-up SCR DeNOx, so priority should be given to low-NOx combustion in the actual DeNOx operation. The low-NOx combustion technology should be especially brought into full play under the overwhelming pressure on ultra-low emissions requirements [3]. However, some power generation enterprises fail to give full play to the role of low-NOx combustion in actual operation, resulting in the subsequent actual operation of flue gas DeNOx exceeding the designed output and bringing about a series of adverse effects such as ammonia escape exceeding the standard and air preheater blockage. On the other hand, some power generation enterprises excessively pursue NOx control effect of low-NOx combustion, resulting in adverse effects such as reduced combustion efficiency of boilers, slagging and high-temperature corrosion, steam temperature deviation or excessive fluctuation. Therefore, the synergistic optimization of low-NOx combustion and SCR DeNOx has become an important operational issue for NOx control in current coal-fired power plants.

| Burner Arrangement  | Nox Concentration (mg/m³) |
|---------------------|---------------------------|
|                     | Bitumite | Lignite | Meagre Coal | Anthracite |
| Rangential Firing   | 250      | 300     | 500         | /          |
| Wall Firing         | 300      | 300     | 550         | /          |
| W Flame Firing      | /        | /       | 800         | 1000       |

At present, the NOx generation concentration of pulverized coal furnace using low-NOx combustion technology is listed in Table 1. In actual operation, it should not only give full play to the furnace NOx control ability with low-NOx combustion system, also avoid blind pursuit of low NOx control indicators. It should follow the four basic principles: safety, economy, environmental protection, adjustability, which is to ensure the lowest concentration of NOx formation on the basis of boiler safety and its adjustability according to the real-time boiler load and the change of the coal. If necessary, the combustion adjustment test should be carried out to determine the economic operation curve, that is to adjust the NOx concentration of DeNOx reactor inlet and the SCR DeNOx ammonia injection amount via the low-NOx combustion control to satisfy the requirement of emission standards, and realize the low DeNOx reactor inlet combustion and the economic operation of the SCR DeNOx taking the boiler efficiency and DeNOx operation cost into account, determining economic operation curves under different load conditions and implementing the coordinated operation of the two technologies.

3. Emission control

In addition to the requirements of ultra-low emission emission targets, environmental protection regulatory authorities have significantly strengthened the supervision and assessment of pollutant emissions in recent years. In order to meet the regulatory requirements and avoid environmental
assessment, some power generation enterprises further increase their own emission standards on the basis of meeting the required standards. For example, some power generation enterprises require desulphurization efficiency and DeNOx efficiency to reach the design value on the basis of standard discharge of environmental protection facilities. However, when the inlet pollutants are lower than the design value, too much emphasis on removal efficiency will lead to unreasonable operation [4]. As shown in Figure 1, the control value of desulfurization efficiency in actual operation of a desulfurization device is as high as 99.742%, but the concentration of SO$_2$ emission value is only about 12 mg/m$^3$, which necessitates the increase of the slurry circulation amount and thus results in increased energy consumption of desulfurization. For another example, although the environmental protection department requires that the hourly average cannot exceed the standard, but some power generation enterprises require that the half-hourly mean does not exceed the standard. In order to meet the standard, the operators have to control the emission index to a very low level. As shown in Figure 1, in the actual operation of a power plant, the indexes of NOx, SO$_2$ and dust are controlled at 17, 12 and 1.8 mg/m$^3$ respectively, which are far below the requirements of 50, 35 and 10 mg/m$^3$ for ultra-low emission. When the NOx index is controlled to such a low level, excessive ammonia injection is often required in the actual operation, which leads to problems such as excessive ammonia escape and air preheater blockage. Desulfurization and dust remover are run in the mode of maximum output, resulting in a great waste of energy consumption.

![Figure 1. The emission concentration curve of a typical 600MW unit.](image)

In view of the above problems, power generation enterprises should make more attempts in operation management and try to control the emission concentration at about 80% of the emission limit value under the premise of meeting emission standards to reduce the energy consumption and material consumption of environmental protection facilities, and avoid adverse impact on boiler auxiliary equipment. For DeNOx facilities, on the basis of giving full play to the role of low-NOx combustion, SCR DeNOx efficiency can be appropriately reduced, so as to reduce the material consumption of ammonia injection, ammonia escape, avoid air preheater blocking and extend the service life of the catalyst. For the desulfurization facility, the slurry circulation pump opening mode under different desulfurization loads [5] and the operating parameters such as the PH value of the double tower with double circulation configuration [6] can be fully optimized to reduce the energy consumption and material consumption as far as possible. For dust remover, which usually involve the operation of the dry dust catcher, collaborative dedusting in desulfurization facilities, WESP and so on many devices [7]. As for the early unit that adopts WESP with a relatively large design margin, the output distribution of each equipment can be adjusted in different load and the entrance dust concentration in actual operation to give full play to the desulfurization facilities collaborative dedusting, avoid all the equipment operated in the largest output mode to reduce energy consumption and the wastage of equipment.
4. Energy-saving and cost-reducing

At present, power generation enterprises have a weak awareness of energy saving and consumption reduction in operation. There are widespread deficiencies in system resistance control, catalyst, filter bag life control, the balance between coal quality and output of environmental protection facilities, and the application of energy-saving technologies. As shown in Figure 2, except fixed depreciation and financial costs, what accounts for a large proportion in the operation cost of ultra-low emission are the cost of DeNOx reductant/desulfurization absorber, SCR catalyst/filter bag replacement and energy consumption (electricity consumption and steam consumption) and they are still adjustable. From the perspective of energy saving and consumption reduction management, the following aspects should be considered:

(1) Strengthen system resistance control

In general, as long as serious ash accumulation and blockage do not occur, the resistance of ultra-low emission flue gas system should be maintained at a relatively stable level. In daily operation, the ash blowing control, shutdown inspection and ash removal should be strengthened. The abnormal increase of resistance should be analyzed and dealt with in time, so as to minimize the fan power consumption and equipment damage [8]. In particular, great attention should be paid to the air preheater blockage caused by the escape of DeNOx ammonia. The DeNOx device should be operated within the designed performance range, and the operation analysis and optimization should be carried out regularly to ensure the stable and efficient operation of the DeNOx device.

(2) Enhance catalyst/filter bag life control

Daily operation of DeNOx device and bag filter should be strictly in accordance with the procedures. The running status of catalyst and filter bag are supposed to be paid close attention. For example, the import and export of NOx concentration, dust concentration, gas temperature should be maintained within the design range. The soot blower operation management should be strengthened. Every failure should be checked; dust cleaned and the damaged catalyst/filter bag replaced in time. Besides, third-party technical service providers should be entrusted to detect the catalyst/filter bag, evaluate the performance and residual life of catalyst/filter bag regularly, find out reasons for abnormal attenuation and rectification and take measures to extend the service life of catalyst/filter bag as long as possible.

(3) Synergistic consideration of environmental facility design effort and coal procurement costs

Figure 2. Ultra-low emission costs of a 2×600MW unit.
When the design output of environmental protection facilities and the actual operating margin is large, inferior coal can be used appropriately to reduce the procurement cost of coal. For example, the pursuit of high parameter and high configuration in previous ultra-low emissions transformation projects has led to the imbalance between the coal procurement cost and desulfurization cost. Enterprises, on the one hand, used expensive low-sulfur coal; on the other hand, used the desulfurization device that has a large margin. In view of this problem, some power generation enterprises have optimized the way of coal blending and burning. On the premise of ensuring the standard emissions and giving full play to the desulfurization device design, the coal procurement cost is significantly reduced and the power generation benefit is significantly improved.

(4) Adopt energy-saving technology

In view of the high energy consumption of current ultra-low emission, some existing energy-saving technologies have achieved good application effects. For example, urea pyrolysis is substituted by hydrolysis or electric heating is substituted by high temperature flue gas heat transfer; ESP can be configured with different types of high-efficiency power supply according to the characteristics of dust and the conditions of flue gas; the electric heating device is substituted by steam heating device, etc. Moreover, qualified power generation enterprises could consider reducing ultra-low emission energy consumption level through energy-saving transformation.

5. Conclusion

Although the theoretical limit value of ultra-low emission pollutants is not much lower than the original standard for the emission of atmospheric pollutants in thermal power plants, the correspondingly increased consumption of reducing agent, absorber and catalyst is limited. However, in actual operation, due to insufficient coordinated optimization operation among various environmental protection facilities, irrational emission index control, and inadequate energy saving and consumption reduction management, the economic efficiency of operations of some units is poor at present. In subsequent operations and maintenance management, coordinated operation should be strengthened between the environmental protection facilities; a reasonable control of pollutant emissions targets should be carried out on the premise of meeting emission standards; the control on system resistance, coal quality, catalyst/filter bag life should be enhanced; partial energy-saving technological transformation should be implemented to ensure the environmental protection facilities are operated in a stable, efficient and economic level.

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