Analysis of carbon verification calculation methods and emission reduction measures for thermal power plants

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Abstract. With the country's increasing emphasis on carbon verification, the carbon trading market has developed rapidly. How to verify the carbon verification amount of thermal power plants by themselves has become an urgent issue. This article explains the calculation method and precautions of the carbon verification amount. From the aspects of coal burning, fuel oil, desulfurizing agent, and plant power consumption, the analysis method of reducing CO₂ was analyzed, and the emission reduction effect was obvious. It provides a direction for power plants to actively organize carbon inspections, find out the verification situation in time, and better conduct annual carbon trading.

1. Introduction

The climate issue has become a global issue, and many large companies in countries around the world are looking for ways to reduce energy consumption and carbon verification. China has suffered from the deterioration of its own environment in recent years and the pressure of the international community on China's carbon verification. The source of CO₂ emissions in China mainly comes from the combustion of fossil fuels. In China, coal as a fossil fuel has an absolute absolute status in the primary energy consumption structure [1]. Coal consumption accounted for more than 66.0% of total energy consumption in 2014. However, China's natural gas reserves and production are relatively poor, and it needs to rely on a large number of imports every year. At the same time, in terms of China's oil reserves and production, there is a big contradiction between supply and demand [2]. Coal-fired power generation and heating are mainly used in thermal power plants, which accounted for more than 50% of total coal consumption in 2004 [3]. It is of great significance to study and calculate the carbon verification amount of thermal power plants and analyze its emission reduction methods and measures.

2. Carbon emissions calculation method

When conducting a carbon verification of a thermal power plant, the first step is to determine the accounting boundary of the plant. The accounting boundary is the boundary constituted by the emitting unit's accounting for the source of greenhouse gas emissions. Usually, it is the scope of production and operation-related activities controlled by the emitting unit within the geographic boundary of the
emitting unit. The accounting boundary is generally based on the legal person of the power plant to identify and calculate the CO$_2$ emissions generated by all production facilities within the boundary. CO$_2$ emission sources include fossil fuel combustion emissions, desulfurization emissions, and electricity purchased outside the power plant. The fossil fuels include fuel oil for power generation, boiler-assisted combustion (start-up and steady combustion), fuel consumption of office vehicles and production vehicles in the factory.

2.1. Calculation of CO$_2$ emissions from fossil fuels

Fossil fuel CO$_2$ emissions calculation formula is:

$$E = AD \times EF$$

(1)

Where $E$ is CO$_2$ emissions, $AD$ is activity level, $EF$ is emission factor.

2.1.1. Activity level. Activity level is the amount of activity that quantifies the production or consumption activities that cause greenhouse gas emissions. Its calculation formula is:

$$AD = FC \times NCV$$

(2)

Where $FC$ is the consumption of fossil fuels, $NCV$ is the average low heating value of fossil fuels. The consumption of fossil fuels should be determined according to the enterprise energy consumption account or statistical reports. In actual statistics, there are two kinds of statistical methods for fossil fuels: monthly consumption and annual consumption. Some power plants have detailed the statistics of daily consumption. The average low-level heating value of fossil fuels is calculated according to the statistical method of consumption to obtain the monthly and annual average values. Monthly average low heating value, annual average low heating value is weighted average of daily average low heating value, weight is daily fuel consumption. To simplify the calculation, the annual average low heating value can also be obtained by weighting the average monthly low heating value, and its weight is the monthly fuel consumption. The statistics of coal burning are based on the amount of coal in the furnace, the auxiliary oil is based on the operating account statistics, and the fuel for office and production vehicles is based on the refueling invoice. The low-calorific value of coal combustion is measured at least once a day, and the low-calorific value of oil-fired power plants generally do not perform test measurements [7].

2.1.2. Emission factor. An emission factor is a coefficient that quantifies the amount of greenhouse gas emissions per unit of activity level. Its calculation formula is:

$$EF = CC \times OF \times 44/12$$

(3)

Among them, $CC$ is the carbon content per unit calorific value of fossil fuels, $OF$ is the carbon oxidation rate of fossil fuels, $44/12$ is the molecular mass ratio of carbon dioxide to carbon. Unit heat value and carbon oxidation rate of fuel are calculated at recommended values [5].

The formula for calculating the carbon content per unit heating value of coal is:

$$CC = \frac{C_{coal}}{NCV_{coal}}$$

(4)

Among them, $CC$ is the carbon content per unit calorific value of coal burning, and $C_{coal}$ is the carbon content of coal burning.

For the coal content of the unit calorific value of carbon content, the enterprise should collect the reduced sample every day, on the last day of each month, mix the reduced samples obtained every day
of the month, and measure its elemental carbon content. The annual average unit calorific value carbon content is obtained by weighting the average monthly weight, the weight is the amount of coal. If the elemental carbon content power plant has not been tested, the default value can be adopted according to the type of coal burned [5], or the dry carbon content can be calculated by empirical fitting formulas according to the literature [8], [9], [10]. Converted to the receiving base, the formula is:

$$C_d = 35.411 - 0.199V_d - 0.341A_d - 0.412S_{d,d} + 1.632Q_{gr,d}$$  \hspace{1cm} (5)

After a large number of data comparisons, the difference between the measured $C_d$ value and the fitted $C_d$ is generally within 2.00%.

The carbon oxidation rate is calculated as:

$$OF_{coal} = 1 - \frac{G_{slag} \times C_{slag} + G_{ash} \times C_{ash}/\eta_{d,c}}{FC_{coal} \times NCV_{coal} \times CC_{coal}}$$  \hspace{1cm} (6)

Among them, $G_{slag}$ and $G_{ash}$ are the output of slag and fly ash, $C_{slag}$ and $C_{ash}$ are the slag and fly ash carbon content, which is the efficiency of dust collector.

In the calculation of slag and fly ash, it can be calculated on an annual basis or on a monthly basis. If the power plant has performed performance tests on the dust collector or has performed technical renovation work, the dust removal efficiency is subject to the test results. Slag output and fly ash output should be measured on actual basis and recorded monthly. If the weighing value cannot be obtained, the estimation method in "DL/T 5142-2002 Thermal Power Plant Ash Removal Design Regulations" can be used for estimation. Its estimation formula is:

$$G_{hz} = G_m \left( A_{ar} + \frac{Q_{net,v,ar} \times q_4}{33870 \times 100} \right)$$  \hspace{1cm} (7)

Among them, $G_{hz}$ is the total ash and slag production, $G_m$ is the amount of coal burned, $A_{ar}$ is the base ash received, $Q_{net,v,ar}$ is the base calorific value received, and $q_4$ is the heat loss of incomplete combustion.

The amount of ash, fly ash is distributed according to the furnace type [4]. $q_4$ is provided by the boiler manufacturer. After the power plant has been put into operation, it has basically done boiler performance tests or boiler technical renovation work. The design value and the measured value have a large deviation. In actual calculation, $q_4$ is based on the test result.

2.2. Calculation of CO2 emissions during desulfurization

For coal-fired units, all are equipped with desulfurization devices. The effective component of the desulfurizing agent used in the desulfurization process is carbonate, so CO2 will also be generated in the desulfurization process. The calculation formula is:

$$E_d = CAL \times EF_k$$  \hspace{1cm} (8)

Among them, $E_d$ is the amount of carbon dioxide check in the desulfurization process, $CAL$ is the carbonate consumption, $EF_k$ is the desulfurizer check factor, and $k$ is the type of desulfurizer.

In the process of CO2 check and calculation in the desulfurization process, the conversion rate of the desulfurization agent is taken as 100%, and the desulfurization agent verification factor is calculated according to the literature [4].

2.3. Calculation of net purchased electricity CO2 emissions

The formula for calculating the CO2 emissions of net purchased electricity is:
Among them, $E_e$ is the net purchased electricity CO$_2$ emissions, $AD_e$ is the net purchased electricity, and $EF_e$ is the net purchased electricity verification factor.

The activity level data of the net purchase of electricity is based on the readings recorded by the electricity meter of the power generation enterprise. If not, the data on the settlement voucher such as the electricity invoice or statement provided by the supplier can be used. Electricity emission factors should be calculated according to the production location of the enterprise and the current Northeast, North, East, Central, Northwest, and Southern Power Grid divisions, and the corresponding regional grid emission factors announced by the national authority in the most recent years should be used for calculation.

3. Emission reduction analysis

3.1. Analysis of CO$_2$ emission reduction from coal combustion

It can be found from the calculation process of coal-fired CO$_2$ emissions that the carbon oxidation rate is the main factor in reducing CO$_2$ emissions. In the actual carbon inventory of the power plant, it was found that the carbon content of slag in some power plants is as high as 15%, and the carbon content of the slag is too high, resulting in increased coal consumption for power generation. The carbon content of fly ash is the key factor determining the heat loss $q_4$ of incomplete combustion. For every 1% increase in the carbon content of fly ash, the coal consumption for power supply increases by 0.8~2.09g/kW.h according to the capacity of different units [12]. Taking a 600MW unit burning bituminous coal, the annual utilization hours of the unit are regarded as 5000 hours, the carbon content of fly ash is reduced by 1%, and the coal consumption for power supply is considered to be reduced by 0.8%. It is known from experience that a meal of bituminous coal is checked for two CO$_2$. CO$_2$ can reduce emissions by about 4,800 tons, with considerable emissions reductions. Therefore, reducing the carbon content of slag and fly ash and increasing the carbon oxidation rate are of great significance for reducing the coal consumption for power generation and heating and reducing the level of CO$_2$ verification activities. The carbon content of slag fly ash can be reduced by changing the height of the flame center and extending the residence time of the fuel in the furnace. The oxygen amount can be appropriately increased in the ash area, the fineness of pulverized coal can be reduced, and the air distribution can be adjusted reasonably. Increasing the dust removal efficiency is beneficial to increase the carbon oxidation rate. For the improvement of dust removal efficiency, you can adjust the smoke exhaust temperature of the dust collector to avoid condensation of the flue gas and stick to the electrostatic precipitator, which will cause the dust removal efficiency to decrease, while controlling the flow rate of the flue gas and reducing secondary dust. And during normal maintenance, the heat insulation and sealing of the pipes and the body of the dust collector in the dust removal system should be checked regularly, and the unqualified parts should be replaced in time.

3.2. Analysis of CO$_2$ emission reduction of fuel oil and purchased electricity

Fuel oil is divided into boiler auxiliary oil and office and production vehicle oil. For boiler auxiliary oil, it is mainly used for boiler start up and stable combustion. Reduction of auxiliary oil consumption can be achieved by strengthening the training of operating technicians' professional knowledge and improving their operating capacity, reducing the number of non-stop times of the unit and improving the unit's low-load stable combustion technology. When conditions permit, the ignition device can be optimized to reduce the amount of starting fuel. After the unit is put into production, the purchased electricity is mainly used for the power consumed by the plant when the unit is completely stopped. Reduction of purchased electricity can be achieved by reducing the number of unit shutdowns.
3.3. Analysis of CO2 emission reduction in desulfurization process
When measuring the amount of CO\textsubscript{2} in the desulfurization process, the conversion rate of the desulfurizing agent was 100%, which was not reached in practice. Taking a 600MW unit burning bituminous coal, the annual utilization hours of the unit are regarded as 5,000 hours, the desulfurization is wet desulfurization, and the desulfurization efficiency is 95%. For example, a unit consumes about 40,000 tons of desulfurizing agent per year, and the desulfurization efficiency is increased by 1%. Desulfurizer consumption reduced by about 500 tons, CO\textsubscript{2} verification reduced by about 200 tons.

Desulfurization agent For wet desulfurization, setting the appropriate pH value and maintaining the stability of PH value are the key factors to improve the desulfurization efficiency. Adjusting the proper liquid-gas ratio can ensure that the slurry is in full contact with SO\textsubscript{2}. While ensuring the desulfurization efficiency, the running time of the high circulation pump can be appropriately increased, which can increase the contact time between the slurry and SO\textsubscript{2}. Strengthen the monitoring of the air supply from the oxidizing fan to the absorption tower to complete the oxidation reaction, improve the dust removal efficiency, and effectively prevent nozzle clogging. For dry desulfurization, the uniformity of the desulfurizer and coal combustion can be improved, and the fineness of the desulfurizer can be appropriately reduced.

3.4. Analysis of CO2 emission reduction per unit power supply
During the power plant inspection process, it was found that the power consumption rate of some power plants was above 5%. For the same grid-connected power, reducing plant power consumption and coal consumption for power supply, thereby reducing power generation and coal consumption, is ultimately important for reducing CO\textsubscript{2} verification. The power consumption rate of the plant can be reduced by optimizing the lighting layout of the production plant and replacing the energy-efficient lighting facilities. Whether the auxiliary machine operation mode is reasonable or not has a great impact on the plant's power consumption and power supply coal consumption. In order to fully prepare for carbon trading, power plants should promptly request relevant authoritative units to conduct carbon inspections of themselves. The power plant shall divide separate relevant departments and relevant persons responsible for the collection of basic data for carbon verification calculations. In order to truly and accurately reflect the inspection amount of the power plant, it is recommended to verify the inspection situation in recent years. At the same time, the relevant data collection department should standardize the daily data management to prevent data loss from affecting subsequent calculations.

4. Summary
(1) When calculating the carbon verification of the power plant, the data must be true and reliable, and the data ledger collection of coal chemical analysis for the furnace must be standardized. The maximum possible refinement of the calculation process. At the same time, the statistics of auxiliary fuel consumption, desulfurizer consumption and other data are performed as much as possible for each unit, which is convenient for comparing the verification between units, and is conducive to unit optimization.

(2) During the operation of the unit, the carbon content of slag fly ash was reduced by various means, and the dust removal efficiency was improved, thereby reducing the amount of CO\textsubscript{2} verification during coal combustion. For fuel oil, the operation technicians can be trained to stabilize the operation of low-load units and reduce the number of non-stop operations. Increasing the desulfurization efficiency in the desulfurization process can reduce the consumption of desulfurizers, thereby reducing the CO\textsubscript{2} verification due to desulfurization. By optimizing the operation of lighting equipment and auxiliary equipment in the plant area, the power consumption rate of the plant can be reduced, and CO\textsubscript{2} emission reduction can be achieved in the end.

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