Low Carbon Environmental Benefit Analysis on Electricity Production Based on Comprehensive Environmental Cost

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Abstract. Research on environmental cost calculation method for electricity production and benefit assessment method considering low-carbon energy saving, can promote the realization of low-carbon production in power industry. First, the measurement for environmental factors and costs were studied in the paper, and then the way to realize low carbon benefit calculation based on comprehensive environmental cost was introduced. Finally, the calculation results of low carbon environmental benefit in a certain area were obtained, and the effect of low carbon production on generation plan, network loss and user side were verified.

Introduction

The main production characteristics of power industry is dominated by coal, the production process will adversely affect the external environment. Accordingly, with the development of electric power production, the environmental control cost for the restoration of external environment will continue to be increased. The measurement for environmental factors and costs were studied in the paper first, and then the way to calculate environmental cost of each pollutant through environmental factors and cost equivalents was introduced, and the low carbon environmental benefit calculation model based on comprehensive environmental cost was put forward. Finally, the effect of low carbon production on generation plan, network loss and user side were verified through an example.

The Calculation of Environmental Factors

According to calculation methods and ideas in guideline, the calculation models for each environmental factor can be established by using the power generation, resource consumption, fuel type, pollutant emissions and other indicators of each unit in power system.

(1) Average carbon dioxide emission factor

$$f_{CO_2} = \frac{M_{CO_2}}{Q} = \frac{FC_i \times NVC_i \times h_{CO_2,i}}{Q} \tag{1}$$

In the formula, M_{CO_2} is the total amount of CO_2 emissions; Q is the total amount of unit on grid electricity; FC_i is the unit consumption of fuel i; NVC_i is the net calorific value of fuel i (energy content, GJ / mass or volume unit); $h_{CO_2,i}$ is the CO_2 emission factor of fuel i; i is the kind of fossil fuels that consumed by unit.

(2) Average sulfur dioxide emission factor

$$f_{SO_2} = M_{SO_2} / Q \tag{2}$$

In the formula, M_{SO_2} is the total amount of SO_2 emissions, and it can be calculated by monitoring;

Q is the total amount of unit on grid electricity.

(3)Average nitrogen oxide emission factor

$$f_{NO_x} = M_{NO_x} / Q \tag{3}$$

In the formula, M_{NO_x} is the total amount of NO_X emissions, and it can be calculated by monitoring; Q is the total amount of unit on grid electricity.

(4) Average PM emission factor

$$f_{PM} = M_{PM} / Q \tag{4}$$

In the formula, M_{PM} is the total amount of PM emissions, and it can be calculated by monitoring; Q is the total amount of unit on grid electricity.

The Calculation of Environmental Cost

The Origin of Environmental Cost

After the introduction of carbon trading mechanism, the total cost of electricity production is the sum of production cost and the environmental cost, as shown in Fig. 1.

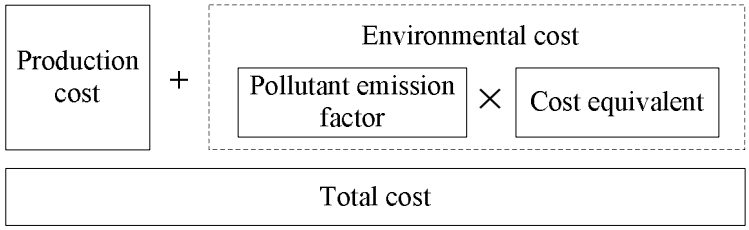

Figure 1 The Structure of Total Cost

In this paper, the environmental cost is divided into two categories, one is the resource consumption cost, and the other is the pollution control cost. The resource consumption class mainly refers to coal consumption, and in this paper, coal consumption and water consumption cost are calculated in production cost. Environmental cost mentioned in this paper refers to the cost that beside above production cost, when the power plant use this part of resource, other companies can not use it any more and they will generate the opportunity cost, so the power plant need to pay additional fees for such resources consumption.

Pollution control class refers to the pollutants that have impact on environment, mainly including CO_2, SO_2, NO_x and solid particles. So a series of measures need to be taken in order to limit emissions within a line, but these measures need to spend some costs and these costs constitute a comprehensive environmental cost.

The Estimation of Cost Equivalent

Pollutant cost equivalent is the cost of per unit pollutant emission. With the adjustment of pollution tax and the construction of national carbon trading market, the pollution tax and carbon price will be more in line with the actual cost of pollution control.

(1) The estimation of CO_2 cost equivalent

Because CO_2 is the most important factor for global warming, other country's carbon tax as the standard, the current carbon tax policy in China is not implemented, carbon price in China's carbon market can be used as the standard for CO_2 cost equivalent.

(2) The estimation of other pollutants cost equivalent

For sulfur dioxide, nitrogen oxides, calculating based on "Management on PollutantDischarge

Fee Standard" and determining the sulfur dioxide pollution fee is 1.2 yuan /kg, nitrogen oxide is also 1.2 yuan /kg. The specific cost equivalentsof sewage and solid particulatehave no relevant policies.

The Calculation of Environmental Costs

By measuring the environmental factors and cost equivalents of pollutants, the management cost of the unit pollutants can be obtained. The average pollutant emission factor multiplied by the pollution control cost equivalent, can get the comprehensive environmental cost that should be paid by unit electricity.

$$\begin{aligned} C_{Com} &= f_p \times e_p \\ &= f_{CO_2} \times e_{CO_2} + f_{SO_2} \times e_{SO_2} + f_{NO_2} \times e_{NO_2} + f_{PM} \times e_{PM} \end{aligned} \tag{5}$$

Low carbon environmental protection comprehensive benefit assessment model

Low carbon environmental protection comprehensive benefit assessment model

The low carbon and environmental protection comprehensive benefit in electric power production is the sum of the benefit of primary energy conservation and the benefit from the reduction of all kinds of pollutant emissions by power plants.

$$E_{Com} = E_{CO_2} + E_{SO_2} + E_{NO_x} + E_{PM} \tag{6}$$

In the formula, E_{Com} is the low carbon comprehensive benefit of electricity production; E_{CO_2} , E_{SO_2} , E_{NO_x} , E_{PM} is the emission reduction benefit of carbon dioxide, sulfur dioxide, nitrogen oxides and solid particles respectively.

The external cost that had been saved (ie, comprehensive environmental cost) during the lowcarbon electricity production, can be understood as a lowcarbon comprehensive benefit. The low carbon environmental protection comprehensive benefit of electricity production is the negative value of environmental cost.

$$E_{Com} = -1^* C_{Com} \tag{7}$$

Comprehensive Benefit Evaluation Process

By measuring raw data from each power plant, the average emission factor of carbon dioxide, sulfur dioxide, nitrogen oxide and solid particle were obtained, and the emission factor multiplied by the total generating capacity of grid can get the total emission amount of each pollutant indicator. By multiplying the separated cost equivalent and the total amount of emissions, the low carbon environmental protection comprehensive cost of each pollutant can be obtained, the total low carbon environmental protection comprehensive cost can be obtained by adding each pollutant cost mentioned above, as shown in Fig. 2.

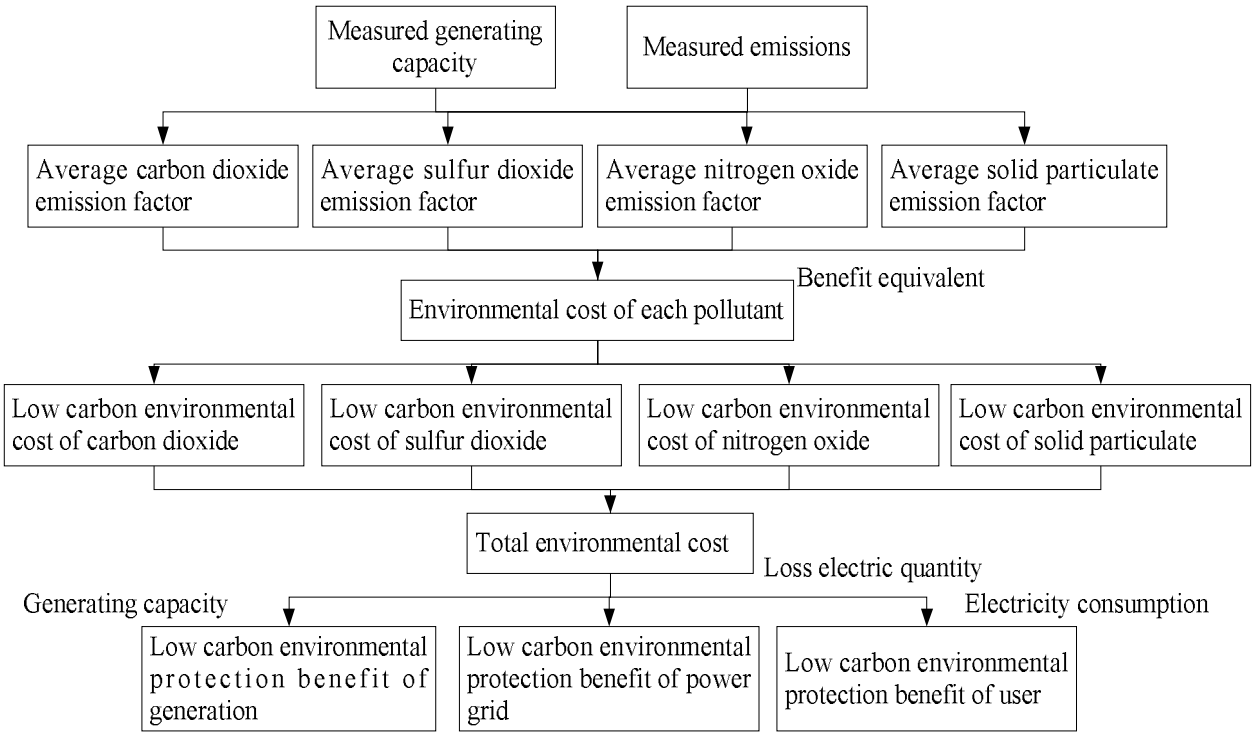

Figure 2 Comprehensive Benefit Evaluation Process

Example Analysis

Example analysis based on the actual data of one province, measured data including generating capacity of each generation unit, CO_2, sulfur dioxide, nitrogen oxide emissions per ton of coal produced were collected. Take power generation standard coal consumption of 292g/kWh. Average carbon dioxide emission factor in thermal power unit is 0.00015184t/kWh, the average sulfur dioxide emission factor is 0.000001022t/kWh, the average nitrogen oxide emission factor is 0.00000216t/kWh, the averagesolid particulate emission factor is 0.000000292t/kWh,as shown in Table 1 and Table 2.

Table 1The Calculation of Average Emission Factor

Power plant	Average carbon dioxide emission factor[t/kWh]	Average sulfur dioxide emission factor[t/kWh]	Average nitrogen oxide emission factor[t/kWh]	Average solid particulate emission factor[t/kWh]
Thermal power plant	0.00015184	0.000001022	0.00000216	0.000000292

The low carbon environmental protectioncomprehensive benefit can be calculated through the benefit evaluation process.

Table 2The Figure of Low Carbon Environmental Protection Benefit

	Carbon dioxide	Sulfur dioxide	Nitrogen oxide	Solid particulate
Emission factor [t/kWh]	0.00015184	0.000001022	0.00000216	0.000000292
Total emissions [t]	30031775	202137	427217	57753
Benefit equivalent [yuan/kg]	0.03	1.26	1.2	0.945
Low carbon environmental protection comprehensive benefit [yuan/kWh]	0.0045552	0.00128772	0.00259296	0.00027594
Total low carbon environmental protection comprehensive benefit [yuan/kWh]	0.008712			

Conclusion

As the power production process produces pollutant emissions, the total electricity cost also includes the environmental cost. Pollutant tax and carbon price can represent the unit environmental costs of each pollutant, combined with the pollutant emissions of per unit generating capacity, environmental cost can be calculated for each pollutant. The benefit generated from low carbon electricity production process, is the comprehensive cost of various pollutants that been saved. The low carbon environmental benefit can reach 0.00871 yuan /kWh through measuring. If part of the electricity in production process can achieve low carbon production, it will bring a very significant low carbon environmental benefit to power generation side, grid side and the user side.

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