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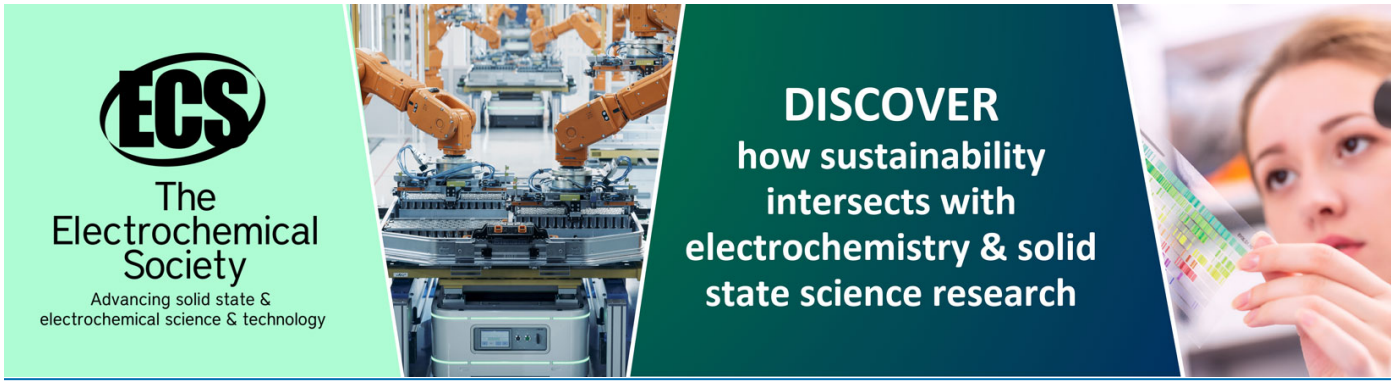

Calculation Model of Priority Generation Considered of Low-carbon Energy Saving

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Abstract. Based on the idea of low-carbon energy saving, this paper uses the differential power accounting method based on the minimum operation mode to calculate the priority power generation. Aiming at the coal consumption and environmental protection efficiency of coal - fired units, a model and evaluation index system are constructed. The coal consumption and environmental protection efficiency are converted into quantifiable economic benefits, which provides the evaluation criteria for selecting the priority generation method of coal - fired units. This paper accounts for Shanghai priority generation of coal - fired units.

1 Introduction

March 29, 2017, the National Development and Reform Commission and the National Energy Board jointly issued on the orderly release of the power plan to open the notice[1], the notice required to reduce the existing coal-fired power generation enterprises planned electricity, the new approved generating units to actively participate Market transactions, take practical measures to implement priority power generation, priority purchase system[2][3].

In order to alleviate the peak peaking problem, it is necessary to require the thermal power plant in the low load period, the stability of the minimum mode of operation to run, so that the equivalent of the entire grid to reduce the base load part of the peak power plant to leave a larger tune Peak space, so as to achieve mitigation peak pressure, with the role of peaking[4]. The minimum operating mode refers to a mode of operation where the system has the largest short-circuit impedance value when the system is running in this mode and the shortest current generated after the short circuit occurs. According to the minimum load of the system for a long time, the minimum number of inputs The most economically efficient units, lines and grounding points[5].

In recent years, most provinces and cities in China coal-fired units have negative growth in power generation situation[6]. While reducing power generation plans, not only to ensure that the power supply, but also to ensure environmental efficiency. Through the analysis and calculation of environmental costs, the establishment of coal-fired unit evaluation index system, accounting for coal-fired units priority power generation.

2 Differential Power Accounting Method Based on Minimum Operation Mode

The difference accounting method based on the minimum operation mode is as follows:

$$\text{Priority generation of coal} - \text{fired units} = \text{Base power} + \text{Differential power} \quad (1)$$

The priority generating amount of the coal-fired unit is composed of two parts of the electric power, the base power and the differential power, among which:

(1) Base power

Single capacity of 300,000 kilowatts and below the conventional coal units, the output can be reduced to at least 50% of the rated capacity; More than 300,000 kilowatts of units, the output can be reduced to at least 60% of rated capacity. The output of less than 60% of the part of the renewable energy peak load shedding part. The general area can take turns 7-10 days of downtime peaking; Peaked in difficult areas or difficult times, depending on the circumstances to extend the downtime peak time."

(2) Differential power

Power generation efficiency sorting differential power: To consider the efficiency difference, the generator set to sort, in the annual base plan to arrange a certain number of hours of energy saving difference. According to the coal-fired power generation enterprises to test the results of coal consumption test, the same unit in the sort of the first unit to give a certain number of hours of power generation awards.

Based on the minimum mode of operation of the difference between the accounting method is as follows:

$$h_i = h_{base} + h_{coal} + h_{green} \quad (2)$$

In the formula, $h_i$represents the power generation hours of the i-th coal-fired units corresponding to the capacity of the unit; h_{coal}represents the generation hours of the unit i corresponding to the coal consumption of coal-fired units; h_{green}indicates that the unit i corresponds to the coal- The number of hours found reward.

3 Study on Energy Efficiency and Environmental Protection Efficiency of Coal - fired Units and Evaluation Index System

3.1 Environmental Cost Analysis and Calculation Steps

The total cost of electricity production should be the sum of production costs and environmental costs (as shown in Figure 1).

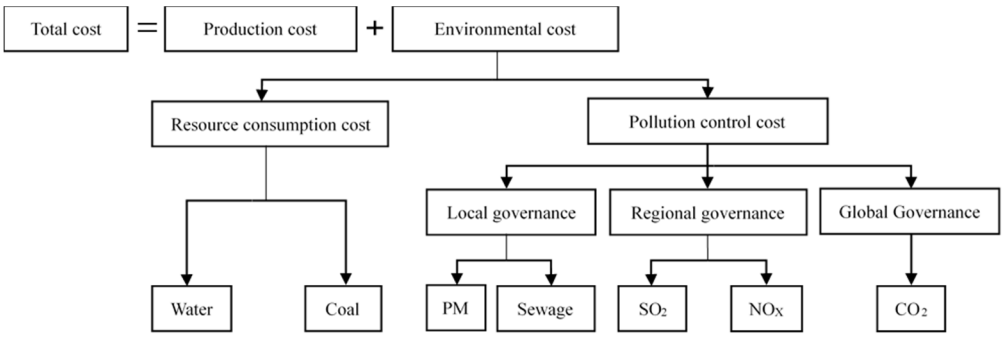

Figure 1 Total Cost of Electricity Production

The environmental cost of electricity production $C_{environment}$ is:

$$C_{environment} = C_{Resource\ consumption} + C_{Pollution\ control} = (C_{Water} + C_{Coal}) + (C_{SO_2} + C_{NO_X} + C_{Sewage} + C_{CO_2} + C_{PM}) \quad (3)$$

In the formula, C_{Water} and C_{Coal}, respectively, water consumption costs and coal resource consumption costs; C_{SO_2} is due to the elimination of electricity production process of sulfur dioxide emissions caused by the cost of governance, the other same.

Figure 2 is the environmental cost analysis and calculation steps:

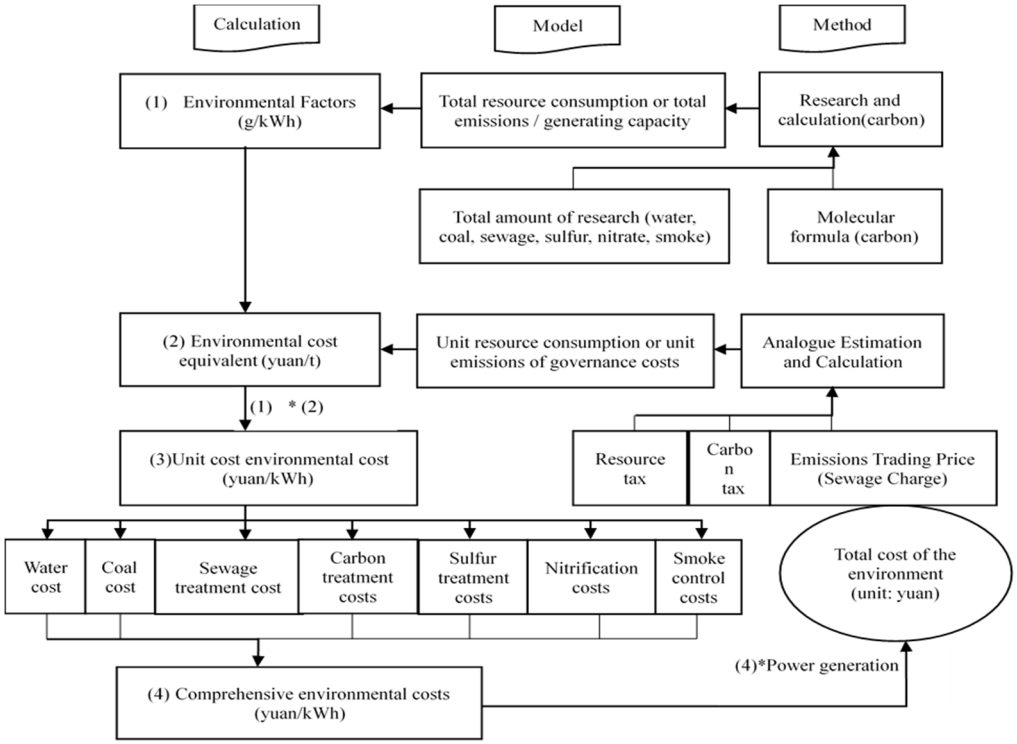

Figure 2 Environmental Cost Analysis Process

3.2 Calculation of Environmental Factors

3.2.1 Calculation of Resource Consumption Factor

The resource consumption factor includes two indicators, water consumption factor and coal consumption rate, which reflect the consumption of water resources and coal resources.

(1) Calculation of water consumption factor

The actual formula for water consumption is:

$$f_{Water} = M_{Water}/Q \quad (4)$$

In the formula, M_{Water} is the total water consumption (t); Q is the total unit power (MWh). The above data can be obtained from the actual survey of the power plant, or based on the average level of different installed capacity units.

(2) Calculation of Coal Consumption Rate Factor

The actual formula for calculating the coal consumption rate is:

$$f_c = M_c/Q \quad (5)$$

In the formula, M_c is the total amount of coal resource consumption (t); Q is the total unit power consumption (MWh). The above data can be obtained from the actual survey of the power plant, or based on the average level of different installed capacity units.

3.2.2Calculation of Pollution Factor

Pollution control factors include five indicators of pollutant pollution, sewage, carbon, sulfur, nitrate and smoke.

(1) Calculation of average emission factors for sewage

The average emission factor for sewage is calculated as follows:

$$f_{sewage} = M_{sewage}/Q \quad (6)$$

In the formula, M_{sewage} is the total amount of sewage (t), can be calculated by the calculation; Q for the unit total power (MWh).

(2) Calculation of Average Emission Factor of Carbon Dioxide

The formula is as follows:

$$f_{CO_2} = \frac{M_{CO_2}}{Q} = \frac{FC_i \times NVC_i \times h_{co_2,i}}{Q} \quad (7)$$

In the formula, M_{CO_2} is the total amount of CO2 emissions (t); Q is the unit total power consumption (MWh); FC_i is the unit fuel i consumption (mass or volume unit); NVC_i is the fuel i net calorific value (energy content , GJ / mass or volume units); $h_{co_2,i}$ is the CO2 emission factor for fuel i (tCO2 / GJ); i is the type of fossil fuel consumed by the unit.

(3) Calculation of average emission factors for sulfur dioxide

The average emission factor for sulfur dioxide is calculated as follows:

$$f_{SO_2} = M_{SO_2}/Q \quad (8)$$

In the formula, the total amount of pollutant SO2 emissions (t), can be calculated by the calculation; for the unit total power (MWh).

(4) Calculation of average emission factors for nitrogen oxides

The average emission factor for nitrogen oxides is calculated as follows:

$$f_{NO_X} = M_{NO_X}/Q \quad (9)$$

In the formula, M_{NO_X} is the total amount of NO_X emissions (t), can be calculated by the calculation; Q for the unit total power (MWh).

(5) Calculation of Average Emission Factor of PM

PM The average emission factor is calculated as follows:

$$f_{PM} = M_{PM}/Q \quad (10)$$

In the formula, M_{PM} is the total PM discharge (t), can be calculated by the calculation; Q for the unit total power (MWh).

According to the actual research data and related literature, the environmental factors of each generating unit are shown in Table 1.

Table 1 The results of environmental factors of generating units

Unit	Unit type	Water	Coal	Sewage	CO_2	SO_2	NO_X	PM
		g/kWh	g/kWh	g/kWh	g/kWh	g/kWh	g/kWh	g/kWh
Coal - fired unit	1000MW	241.148	307.594	3.990	674.554	0.284	0.385	0.081
	600MW	318.840	319.878	34.381	849.953	0.586	0.908	0.080
	300MW	501.193	347.326	120.536	632.694	0.298	1.816	0.090
Hydropower unit	Years of adjustment	--	--	--	--	--	--	--
	Year adjustment	--	--	--	--	--	--	--
	Runoff	--	--	--	--	--	--	--
Gas turbine unit	9E	106	286.53	0.145	450.8	0.003	1.382	0.053
	9F	90	272.32	0.142	432.3	0.003	1.346	0.051
Nuclear power unit	Nuclear power unit	--	--	--	--	--	--	--
Wind turbine	Wind turbine	--	--	--	--	--	--	--

3.3 Calculation of environmental cost equivalents

The so-called environmental cost equivalent refers to the various types of resources for each unit and a variety of pollutants per discharge of a unit to deal with the environment to pay the cost of compensation. For the consideration of the two major environmental costs of resource consumption and pollution control in power production, the unit cost of energy consumption (water and coal) is called the cost of resource consumption. The wastewater, carbon dioxide, sulfur dioxide, nitrogen oxides and The unit management cost corresponding to the discharge of solid particulate matter is called the cost equivalent of pollution control. The following will be the two categories of cost equivalents to make a specific calculation.

3.3.1Calculation of cost equivalence of resource consumption

Resource consumption class cost equivalent is represented by e_r, to measure the long-term adverse effects of primary energy consumption. Different types of primary energy resource taxes are shown in Table 2.

Table 2 Tax rate of China 's resource tax

Tax items	Amount of tax
1.crude	8-30yuan/ton
2. natural gas	2-15 Yuan / thousand cubic meters
3.Coal	0.3-5 yuan / ton
4.other non-metallic ore ore	0.5-20 / ton or cubic meter
5.Black metal ore ore	2-30 yuan / ton
6.Non - ferrous metal ore	0.4-30 yuan / ton
7.Salt	--
8.Solid salt	10-60 yuan / ton
9.Liquid salt	2-10 yuan / ton

3.3.2 Calculation of cost equivalence of pollution control

Pollution control class cost equivalent is represented by e_p, measuring the cost of emissions from various pollutants. For the sewage treatment costs, if the discharge standards only need to levy sewage treatment fees, if there is a class of pollutants still need to levy sewage charges; Sewage charges charge amount = 0.7 yuan × the first three pollutants in the sum of the amount of pollution equivalent, the first and second class pollutants are classified according to the Integrated Wastewater Discharge Standard (GB8978-1996); For excessive pollutants need to be based on the original sewage charges plus 1 times the collection of excessive standard sewage charges. For the cost of carbon dioxide treatment, due to excessive carbon tax levy on the national economy and the impact of corporate resilience, so the current tax will generally be set at 10-50 yuan per ton of carbon dioxide levy. For the sulfur dioxide, nitrogen oxides and solid particles of governance costs, according to China's "sewage charges levy standards management approach" to calculate.

3.3.3Cost equivalence analogue estimate

From the table 3 we can see: China has only carried out the collection of resource tax, carbon tax policy has not yet been implemented, can be similar to the situation at home and abroad to determine the equivalent of emissions trading is still in the pilot phase, it can be in accordance with China's sewage charges collection standards And then determine the value of the relevant equivalent.

Table 3 Tax rate of China 's resource tax

Country / tax	Resource tax (taking coal as an example)	Carbon tax	Emissions Trading Price (Emissions)
The United States	15%-30%	50-80yuan/t	Emissions trading has been implemented
Japan	50%	150-250yuan/t	
The European Union	15-70%	200-300yuan/t	
China	0.3-5yuan/t	0	Emissions trading is carried out in some areas

Water resources tax reference to the implementation of Chaoyang District, Beijing to take 1.1 yuan / kg; for sewage treatment fees, according to emission standards and management practices, the current number of coal-fired The unit and the gas turbine unit will use the sewage treatment system under the impetus of the national policy. The processing cost is 0.27 yuan / cubic meter. For the carbon dioxide tax, according to the actual situation of our country and the international experience (Table 5-3) 10-50

yuan in the middle of 30 yuan / ton; for sulfur dioxide, nitrogen oxides and solid particles, according to "sewage charges collection standard management approach" to calculate the sulfur dioxide pollution fee of 0.632 yuan / kg, nitrogen oxide is also 0.632 Yuan / kg, solid particles due to difficult to detect, so take the average of 3 yuan per ton of coal.

3.4 Calculation of environmental cost

The total cost of the environment (in yuan / kWh) that should be paid for the unit charge, which is:

$$\begin{aligned} C_{\text{synthesize}} &= C_r + C_p \\ &= f_r \times e_r + f_p \times e_p \\ &= f_{\text{water}} \times e_{\text{water}} + f_c \times e_c \\ &\quad + f_{\text{sewage}} \times e_{\text{sewage}} + f_{CO_2} \times e_{CO_2} + f_{SO_2} \times e_{SO_2} + f_{NO_2} \times e_{NO_2} + f_{PM} \times e_{PM} \end{aligned} \tag{11}$$

In the formula, Cr, Cp were the unit power consumption and pollution control class cost.

4 Case Analysis of Differential Power Accounting Based on Minimum Operation Mode

An example analysis of Shanghai. According to the coal consumption of the unit sort, statistics coal-fired units of the power generation hours as shown in the following table 4:

Table 4 The number of hours of coal - fired units to be considered for coal consumption

Unit name	Installed capacity (MW)	Base hours	Coal consumption (t/MWh)	Sorting	Energy reward	Similar rankings reward	The final number of hours of power generation
Waigaoqiao third power plant _8 machine	1000	3004	0.2716	1	The first gear: reward 120 hours	30 hours	3154
Waigaoqiao third power plant _7 machine	1000	3004	0.27255	2			3124
ShangdianCaojing Power Plant _2 machine	1000	3004	0.27572	3			3124
ShangdianCaojing Power Plant _1 machine	1000	3004	0.27698	4			3124
Waigaoqiao third power plant _5 machine	900	3004	0.28937	5		30 hours	3154
Waigaoqiao third power plant _6 machine	900	3004	0.29026	6	The second gear: reward 90 hours		3094
Shidongkou second power plant _1 machine	600	3004	0.29803	7		30 hours	3124
Shidongkou second power plant _2 machine	600	3004	0.30115	8			3094
Waigaoqiao third power plant _4 machine	320	3004	0.30969	9		30 hours	3124
Waigaoqiao third power plant _3 machine	320	3004	0.31122	10			3094
Waigaoqiao third power plant _2 machine	320	3004	0.31173	11	The third gear: reward 60 hours		3064
Wujing second power plant _1 machine	600	3004	0.31351	12			3064
Wujing second power plant _2 machine	600	3004	0.3155	13			3064
Waigaoqiao third power plant _1 machine	320	3004	0.31733	14			3064
Shidongkou Power Plant _4 machine	660	3004	0.32036	15			3064
Shidongkou Power Plant _1 machine	600	3004	0.32046	16	The fourth gear: reward 30 hours		3034
Shidongkou Power Plant _2 machine	600	3004	0.32188	17			3034
Shidongkou Power Plant _3 machine	660	3004	0.32412	18			3034
Wujing Thermal Power Plant _12 machine	300	3756	0.32911	19			3786
Wujing Thermal Power Plant _11 machine	300	3756	0.33462	20			3786

According to the analytic hierarchy process, we can conclude that the weighting factor of this factor is shown in the following table, as shown in Table 5.

Table 5 Number of hours of coal - fired units to be Considered for environmental sequencing

Water	Coal	CO_2	SO_2	NO_X	Solid particles	Sewage
0.0377	0.1823	0.0003	0.3026	0.1246	0.57249	0.00001

According to the above factors, the environmental factors of the thermal power units can be obtained. The units with small environmental factors are given priority, and the calculation results are shown in the following table 6.

Table 6 Number of hours of coal - fired units to be Considered for environmental sequencing

Unit name	Installed capacity (MW)	Environmental factors	Classification bonus	Similar rankings reward
Waigaoqiao second power plant _6 machine	900	0.02173	120	15
Waigaoqiao Power Plant _4 machine	320	0.02322		15
Waigaoqiao Power Plant _3 machine	320	0.02404		
Waigaoqiao second power plant _5 machine	900	0.02411		
Shidongkou Power Plant _4 machine	660	0.02412		15
Shidongkou Power Plant _41machine	600	0.02457	90	
Wujing thermal power plant _11 machine	300	0.02457		
Shangdiancaojing Power Plant _1 machine	1000	0.02471		15
Shangdiancaojing Power Plant _2 machine	1000	0.02483		
Shidongkou Power Plant _2 machine	600	0.02544		
Waigaoqiao third power plant _3 machine	1000	0.02572	60	
Waigaoqiao third power plant _8 machine	1000	0.02583		
Waigaoqiao Power Plant _1 machine	320	0.02736		
Shidongkou second power plant _1 machine	600	0.02755		
Shidongkou Power Plant _3 machine	660	0.02781		
Shidongkou second power plant _2 machine	600	0.02942	30	
Wujing second power plant _2 machine	600	0.02977		
Wujing Thermal Power Plant _12 machine	300	0.03029		
Wujing second power plant _1 machine	600	0.03072		
Waigaoqiao Power Plant _2 machine	320	0.03138		

Combined with the number of power generation base hours and coal consumption and environmental factors caused by the difference in the number of hours, summarized as follows:

Table 7 Analysis on the number of hours of generating electricity and the environmental benefit of coal – fired units

Unit name	Installed capacity (MW)	Priority generation hours	Environmental costs (yuan/MWh)
Waigaoqiao third power plant _8 machine	1000	3214	88.67
Waigaoqiao third power plant _7 machine	1000	3184	89.94
ShangdianCaojing Power Plant _2 machine	1000	3214	84.7
ShangdianCaojing Power Plant _1 machine	1000	3229	86.16
Waigaoqiao third power plant _5 machine	900	3274	91.71
Waigaoqiao third power plant _6 machine	900	3229	101.95
Shidongkou second power plant _1 machine	600	3184	97.56
Shidongkou second power plant _2 machine	600	3124	82.25
Waigaoqiao third power plant _4 machine	320	3259	91.63
Waigaoqiao third power plant _3 machine	320	3214	95.19
Waigaoqiao third power plant _2 machine	320	3094	82.18
Wujing second power plant _1 machine	600	3094	97.66
Wujing second power plant _2 machine 机	600	3094	98.72
Waigaoqiao third power plant _1 machine	320	3124	93.6
Shidongkou Power Plant _4 machine	660	3199	101.8
Shidongkou Power Plant _1 machine	600	3124	83.9
Shidongkou Power Plant _2 machine	600	3124	88.05
Shidongkou Power Plant _3 machine	660	3094	89.49
Wujing Thermal Power Plant _12 machine	300	3816	99.26
Wujing Thermal Power Plant _11 machine	300	3876	92.2

According to the results of statistical analysis, coal-fired units priority to the average number of hours of power generation 3238 hours, the environmental cost of 91.83 yuan / MWh.

5 Conclusion

In this paper, the priority calculation method based on the minimum operation mode is studied deeply, and the following research work is completed:

(1) A comprehensive analysis based on the minimum mode of operation of the difference between the accounting method, the priority of coal-fired units of the two parts were described.

(2) Aiming at the coal consumption and environmental protection efficiency of coal - fired units, a model and evaluation index system are constructed. The coal consumption and environmental protection efficiency are converted into quantifiable economic benefits, which provides the evaluation criteria for selecting the priority generation method of coal - fired units.

(3) This paper accounts for the priority generating capacity of coal - fired units.

Based on the actual operation data of Shanghai power grid, combined with the evaluation and evaluation index system of energy saving and environmental protection efficiency of coal-fired units, the paper analyzes the priority generation of different power consumption based on the minimum operation mode. The calculation results show that the difference calculation method of the minimum operation mode Practicality, the estimated generation of coal-fired units priority generation hours recommended value of 3293 hours.

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