Optimization Method for Grid Purchasing Electricity Under the Constraints of Low-Carbon

LIU Dun-nan[1], YING Yu-hang[1,*] and WANG Hai-chao[2]

[1]*North China Electric Power University, Beijing 102206, P.R. China*
2Anhui Grid Power Trade Center, Anhui 230000, P.R. China

Abstract. World widely speaking, power industry plays an important player in the carbon emission and the carbon emission reduction field, and it is also the main part of the carbon trade market. Carbon constraint in electricity market will profoundly transform the original model of the power generation and electricity trade, and market behavior of every part in electric power market will be substantially changed. In this paper, the impact that carbon emission trade on electricity companies is mainly analyzed. First, optimum background for purchasing electricity of Shenzhen grid is analyzed. Next, optimization method for grid purchasing electricity is analyzed based on data of Shenzhen grid's purchasing electricity. It turns out that Optimization method can offer reliable strategies for grid enterprises purchasing electricity.

1 INTRODUCTION

With the development of carbon emission trade market in our country, in order to achieve the aim of carbon emission reduction, power industry has become the important part. In our country, total emission of electric carbon is great and the growth of that is fast. In 2010, amount of CO_2 emission for electricity industry is nearly 50% of total amount. It proves that carbon emission reduction has high pressure and great potential in our country. Under the low-carbon economic model, traditional electricity industry is faced with tremendously transformed both in external condition and internal developing model.

Under the development of CDM (Clean Development Mechanism), based on carbon trade, grid company can regard energy conservation and environment protection benefit as economic benefit while purchasing electricity. That is to say, synthetically considering the energy conservation and pollutant emission reduction as economic benefit to decide the final optimization method for purchasing electricity.

In order to solve shortage about regardless of power generation external cost, this section suggests an optimization method with considering power generation external cost. Taking the energy conservation and pollutant emission reduction into account and considering production cost and external cost ,at the same time, measuring integrated purchasing electricity cost and instructing grid company to make reasonable purchasing electricity priority. As a results, competence of clean energy grid connection can be improved.

2 Optimization Background for Grid Purchasing Electricity

The current electricity purchasing modes are considered mainly from the three principles (open, justice and fair) and economy. With the increasing emphasis from the whole society on energy-conservation and emission reduction, especially the emission reduction of carbon dioxide, which influences the global climate, is becoming the focus of international attention. Energy conservation, emission reduction and low carbon during electricity production have become the optimization objectives needing equivalent attention besides economic objective. Therefore, grid corporations should transfer the costs of energy conservation, emission reduction and low carbon into economic cost. It means that turning the statistical indices such as energy conservation and pollutant reduction into comparable and reference index and calculating comprehensive purchasing costs to determine purchase optimization scheme. The comparison between before-optimization and after- optimization is shown in Tab.1.

Table 1. Analysis on the influence of electricity purchase optimization on grid corporations and society.

	Grid corporation	**Society**
Economic cost	The average electricity purchasing price rises caused by the change of the electricity purchase structure	Wind power and other clean energies join the power grid. Financial subsidies increased.
Comprehensive cost	Rises	The proportion of clean electricity consumption is increasing, producing the benefits of energy conservation and emission reduction.

3 Optimization Model of Grid Purchasing Electricity Under Constraints of Low Carbon

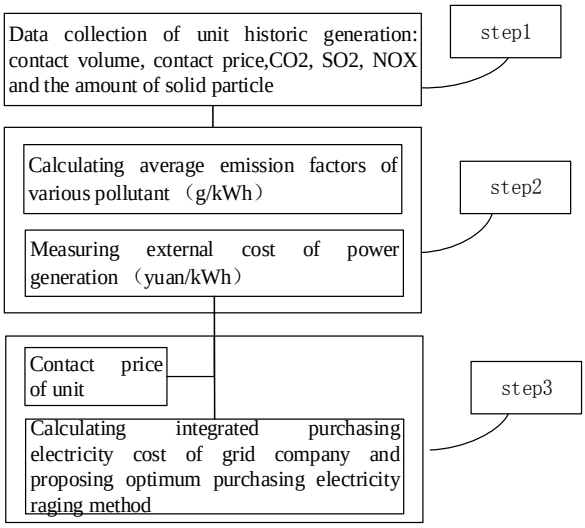

Figure 1. Optimization process of purchasing electricity under constraints of low carbon

3.1. Data Collection

Collecting amount of actual generation, contact volume, contact price, amount of CO2 emission, amount of SO2 emission, amount of NO2 emission, amount of solid particle emission and some other data from existing evaluating system of generating units, monitoring system of pollution emission, forecast system of electric load for a super short period and support system of grid trade.

3.2. Calculation External Cost of Power Generation

(1)Calculating emission factors of CO_2, SO_2, NO_x and solid particle for each unit. The calculation formula is as follows.

$$e_{CO_2,i} = \frac{M_{CO_2,i}}{Q_i} \tag{1}$$

$$e_{SO_2,i} = \frac{M_{SO_2,i}}{Q_i} \tag{2}$$

$$e_{NO_X,i} = \frac{M_{NO_X,i}}{Q_i} \tag{3}$$

$$e_{PM,i} = \frac{M_{PM,i}}{Q_i} \tag{4}$$

In which, $e_{CO_2,i}$ is taken as CO_2 emission factor of unit *i*. $e_{SO_2,i}$ is taken as SO_2 emission factor of unit *i*. $e_{NO_X,i}$ is taken as NO_2 emission factor of unit *i*. $e_{PM,i}$ is taken as solid particle emission factor of unit *i*. $M_{CO_2,i}$, $M_{SO_2,i}$, $M_{NO_X,i}$ and $M_{PM,i}$ are respectively taken as total emission amount of various pollutant of unit *i*.

(2)Synthetically considering of emission factors and unit governance cost of pollutant emission to forecast external cost of power generation. The calculation formula is as follows.

$$C_{EC,i} = C_{CO_2,i} + C_{SO_2,i} + C_{NO_X,i} + C_{PM,i} \tag{5}$$

In which :

$$C_{CO_2,i} = f_{CO_2} \times e_{CO_2,i} \tag{6}$$

$$C_{SO_2,i} = f_{SO_2} \times e_{SO_2,i} \tag{7}$$

$$C_{NO_X,i} = f_{NO_X} \times e_{NO_X,i} \tag{8}$$

$$C_{PM,i} = f_{PM} \times e_{PM,i} \tag{9}$$

In which, $C_{EC,i}$ is taken as external cost of power generation for unit *i*. $C_{CO_2,i}$, $C_{SO_2,i}$, $C_{NO_X,i}$, $C_{PM,i}$ are respectively taken as external cost of various pollutant. f_{CO_2}, f_{SO_2}, f_{NO_X}, f_{PM} are taken as governance cost of unit pollutant emission. Governance cost of unit pollutant emission is the cost should be paid for environment when each kind of pollutant is discharged. It is an artificial variable which can be corrected according to actual situation.

Tab.2 Optimum analog data for company purchasing electricity.

Purchasing Type	Installed Capacity (*MW*)	Contact Price (Yuan /*MWh*)	Generation Amount(GHW)	Amount of emission(ton)			
				CO_2 (1000-ton)	SO_2	NO_x	Solid Particle
Wind power plant 1	50	478	1.14	0	0	0	0
Hydro–power generating unit 2	50	320	2.5	0	0	0	0
Thermal power generating unit 3	900	478	52	406	3593	1624	431
Thermal power generating unit 4	660	478	34	287	2530	1504	353
Thermal power generating unit 5	600	478	28	239	2130	2552	277
Thermal power generating unit 6	300	478	17	148	1328	1797	193
Thermal power generating unit 7	250	466	12	112	2899	4380	381

4 Analysis on Example

With the example, the proposed measuring in this page will be further illustrated. Simulation analysis is carried out for the partial purchasing electricity data of Shenzhen grid in 2014. Detailed optimization process is as follows.

4.1. Collection of Historical Generation Data

Optimum analog data for Shenzhen grid company purchasing electricity is shown in Tab.2.

In Tab.2, Wind power plant 1 has 33 wind generation units of 1.5MW installed capacity, and unit 7 is not installed desulphurization and denitrification device. Considering the impact of desulphurization and denitrification devices on contact volume.

4.2. Calculating the External Cost of Power Generation

(1)Calculating various emission factor pollutant for power generation, the result is shown in Tab.3.

Tab.3 Pollutant emission factors for power generations.

Object of Purchasing Electricity	$e_{CO_2,i}$ (*g/kW·h*)	$e_{SO_2,i}$ (*g/kW·h*)	$e_{NO_X,i}$ (*g/kW·h*)	$e_{PM,i}$ (*g/kW·h*)
Wind power plant 1	0	0	0	0
Hydro–power generating unit 2	0	0	0	0
Thermal power generating unit 3	780.21	0.6899	0.3118	0.0828
Thermal power generating unit 4	833.34	0.7343	0.4366	0.1024
Thermal power generating unit 5	841.03	0.7504	0.8989	0.0974
Thermal power generating unit 6	878.23	0.7874	1.0653	0.1157
Thermal power generating unit 7	892.31	2.3041	3.4816	0.3025

(2)Calculating the external cost of power generation

According to the law for pollutant trade, governance cost of unit pollutant emission is shown as Tab.4.

Tab.4 Governance cost of unit pollutant emission.

Conversion Coefficient	f_{CO_2} (yuan /ton)	f_{SO_2} (yuan /ton)	f_{NO_X} (yuan /ton)	f_{PM} (yuan /ton)
Data	80	3000	3000	1000

Result of power generation external cost is shown in Tab.5.

Tab.5 External cost of power generation.

Prchasing Type	$C_{CO_2,i}$ (yuan /MWH)	$C_{SO_2,i}$ (yuan /MWH)	$C_{NO_X,i}$ (yuan /MWH)	$C_{PM,i}$ (yuan /MWH)	$C_{EC,i}$ (yuan /MWH)
Wind power plant 1	0	0	0	0	0
Hydro–power generating unit 2	0	0	0	0	0
Thermal power generating unit 3	62.42	2.07	0.94	0.08	65.50
Thermal power generating unit 4	66.67	2.20	1.31	0.10	70.28
Thermal power generating unit 5	67.28	2.25	2.70	0.10	72.33
Thermal power generating unit 6	70.26	2.36	3.20	0.12	75.93
Thermal power generating unit 7	71.39	6.91	10.44	0.30	89.04

4.3. Calculating and raging priority order for purchasing power

Calculating and raging integrated purchasing electricity cost of the grid company as priority order for purchasing power. Integrated purchasing electricity cost and priority order is shown in Tab.6

Tab.6 Integrated purchasing electricity cost and priority order.

Object of Purchasing Electricity	$C_{pr,i}$ (yuan /MWh)	$C_{EC,i}$ (yuan /MWh)	Ci (yuan /MWh)	Cost Raging
Wind power plant 1	478	0	478	2
Hydro–power generating unit 2	320	0	320	1
Thermal power generating unit 3	478	65.50	543.50	3
Thermal power generating unit 4	478	70.28	548.28	4
Thermal power generating unit 5	478	72.33	550.33	5
Thermal power generating unit 6	478	75.93	553.93	6
Thermal power generating unit 7	466	89.04	555.04	7

Tab.6 shows that the priority of purchasing hydropower and wind power has been improved with the consideration of electricity production external cost. The priority of purchasing thermal power has dropped because of the increasing of comprehensive cost caused by pollutant emission.

5 Conclusion and Suggestions

Under the background of carbon trading. the optimum plan for Shenzhen power grid purchasing electricity with the consideration of the electric power production externality has been proposed in this paper. The background of Shenzhen Power Grid purchasing electricity optimization has been analyzed and the external cost caused by electricity production has been totally cleared up. The electricity purchasing optimization model with the consideration of external cost of Shenzhen Power Grid Company has been established and the decision －making basis has been put forward, which will help to increase the generation capacity and realizing the energy conservation and emission reduction goal of our country.

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