CO₂ Emission Reduction for Power System Based on Total Emission Control of CO₂ (II): A Case Study

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Abstract—Power industry as the main source of CO₂ emissions, is facing tremendous challenge of CO₂ emission reduction during the periods of "12th Five-year" and "13th Five-year". How to maximize the reduction of power CO₂ emissions under the premise of regional economic development and energy requirements is the significant management objective for administrative department. In this study, a mixed integer stochastic chance-constraint programming model based on CO₂ emission reduction from power industry is applied to the power system in Heilongjiang province, in order to obtain the CO₂ emission reduction schemes of energy conservation, reduction project and power structure adjustment in Heilongjiang province during the periods of the "12th Five-year" and "13th Five-year".

According to the model calculation and the results analysis, the power CO₂ emission growth in periods of the "12th Five-year" and "13th Five-year" are less than 23.82% and 20.13% respectively, significantly lower than the regional CO₂ emission growth. It means the power industry has made a great contribution to CO₂ emission reduction in Heilongjiang province. Meanwhile, the results of model application show that the developed model can meet the management target of maximizing the reduction of power CO₂ emissions, and provide reasonable reference to the administrative department.

Keywords: CO₂ emission reduction; energy conservation; carbon capture and storage; generating expansion planning

I. INTRODUCTION

On November 26, 2009, Chinese government has officially announced actions to control greenhouse gas emissions target that is to reduce 40%-45% CO₂ emissions per unit of GDP by 2020 from the 2005 level. Power industry as the main source of CO₂ emissions is the key object to reduce CO₂ emissions in China. By making reasonable plan to maximize the CO₂ emission reduction and implement low-carbon power is the only way for the sustainable development of the power industry, and of great importance to achieve the overall objective of CO₂ emission reduction in China[1].

The relevant scholars have carried out a series of research on China's CO₂ emissions control [2-9]. Although the achievement is diversified, the overall lack of the angle of the collaborative research on energy conservation, CO₂ reduction project and power structure adjustment.

The researchers in the article "CO₂ Emission Reduction for Power System Based on Total Emission Control of CO₂ (I): Modeling", regards the maximum reduction of CO₂ emissions from power industry during the planning phase through energy conservation, CO₂ reduction project and power structure adjustment as the objective function, a mixed integer stochastic chance-constraint programming model has been developed. In this paper, the established model application research is proceeded, and takes power system in Heilongjiang province as an example.

II. OVERVIEW OF THE CASE STUDY SYSTEM

Considering periods of "12th Five-year" and "13th Five-year" (2011-2015 is the first period and 2016-2020 is the second period), the planning period is ten years.

By the end of 2010, the total installed power generating capacity of Heilongjiang province is about 21.35 million kW, and the installed capacity of coal-fired generating units is 16.97 million kW, account for 91% of the total. In addition, the installed capacity of wind power and hydro power are 2.4 million kW and 0.95 million kW respectively. The CO₂ emission control target is shown in table I.
TABLE I. TOTAL AMOUNT CONTROL TARGET BASED ON PER UNIT OF GDP CO2 EMISSIONS INTENSITY

<table>
<thead>
<tr>
<th>Planning period</th>
<th>GDP (billion RMB)</th>
<th>CO2 emissions intensity (ton CO2/ million RMB GDP)</th>
<th>Falling target (%)</th>
<th>CO2 total emission (million ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base year</td>
<td>2010</td>
<td>10235</td>
<td>2.83</td>
<td>28989</td>
</tr>
<tr>
<td>Target year</td>
<td>2015</td>
<td>18038</td>
<td>2.38</td>
<td>42880</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>27753</td>
<td>1.95</td>
<td>54100</td>
</tr>
</tbody>
</table>

According to the statistical yearbook data of power industry in Heilongjiang province, the power consumption statistics from 2000 to 2012 is shown in Table II. Through the Crystal software, by applying the Monte Carlo stochastic simulation method, regional electricity consumption probability distribution can be simulated as shown in Fig. 1.

TABLE II. ELECTRICITY CONSUMPTION OF HEILONGJIANG PROVINCE FROM 2000-2012. (Unit: hundred million kWh)

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3073.0</td>
<td>371.52</td>
<td>382.07</td>
<td>391.57</td>
<td>412.95</td>
<td>525.5</td>
<td>555.9</td>
<td>597</td>
<td>628.9</td>
<td>669.9</td>
<td>688.7</td>
<td>747.8</td>
<td>802.0</td>
</tr>
</tbody>
</table>

The cumulative electricity probability distribution can be obtained through regional electricity probability distribution. This section will optimize targets of CO2 emission reduction of energy conservation, reduction project and power structure adjustment in Heilongjiang power system during the planning periods under three levels of default probability (0.01, 0.03, 0.05).

III. RESULTS AND DISCUSSION

A. CO2 Emission Reduction of Energy Conservation

According to the planning results, CO2 emission reduction through the energy conservation in the first planning period is 1.5772 million tons, and further reduced 1.3266 million tons in the second period.

B. CO2 Emission Reduction of Reduction Project

"12th Five-year" period, as a result of CCS technology is still in the stage of development, cost and energy consumption is higher, does not yet have the application level to industrialization. As issued by the ministry of science and technology of the "12th Five-year" national carbon capture use and storage of science and technology development plan", by the end of the "12th Five-year", breakthrough a batch of carbon capture, utilization and storage (CCUS) basic theory and key technologies, realize cost and energy consumption significantly reduce, form a megaton CCUS system design and integration capabilities[10], CCS is expected to be applied in "13th Five-year" period.

According to the result of model calculation, "13th Five-year" period in each level of the probability of default, CO2 emission reduction is 4.1425 million tons, 3.8257 million tons and 3.8257 million tons by adopting CCS technology, involving coal unit 1.465 million kW, 1.3602 million kW and 1.3078 million kW.

C. CO2 Emission Reduction of Structure Adjustment

CO2 structure emission reduction is relative reduction, raising the proportion of clean energy power generating by adjusting the power structure, and indirectly reducing CO2 emissions. CO2 structure emission reduction under default probability levels in each planning period is shown in the Table III.

In each default probability level, CO2 structure emission reduction is 6.5185 million tons in the first planning period through the development of clean energy generating units, the second planning period reduce CO2 emission 42.363 million tons relatively. Due to nuclear power get development in the second planning period, so CO2 relative emission reduction in the second planning period is significantly higher than the first planning period.

In particular, CO2 emission reduction of the coal power and gas power in the planning period in the table III in bold is negative, indicating CO2 emissions is new incremental.

Generating capacity of thermal power and clean energy power during each planning period under default
probability levels is shown in Fig. 2.

### TABLE III. CO₂ STRUCTURE EMISSIONS REDUCTION RESULTS IN PLANNING PERIOD

<table>
<thead>
<tr>
<th>Default levels</th>
<th>Relative reduction (ten thousand tons)</th>
<th>Planning period of “12th Five-year”</th>
<th>Planning period of “13th Five-year”</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Coal power</td>
<td>Gas power</td>
</tr>
<tr>
<td>0.01</td>
<td>651.85</td>
<td>-3507.46</td>
<td>-38.78</td>
</tr>
<tr>
<td>0.03</td>
<td>651.85</td>
<td>-2869.74</td>
<td>-14.45</td>
</tr>
<tr>
<td>0.05</td>
<td>651.85</td>
<td>-2550.88</td>
<td>-8.55</td>
</tr>
</tbody>
</table>

![Figure 2. Thermal power and clean energy power generating capacity of every planning period under default probability levels.](image)

**IV. SUMMARY**

In this paper, a mixed integer stochastic chance-constraint programming model based on CO₂ emission reduction from power industry through ways of energy conservation, reduction project and power structure adjustment is applied to the power system in Heilongjiang province. According to the model calculation and the results analysis, CO₂ emission control targets of energy conservation, reduction project and power structure adjustment of Heilongjiang province during the periods of the "12th Five-year" and "13th Five-year" are obtained. Through the model recommendation, power CO₂ emission growth in periods of the "12th Five-year" and "13th Five-year" are less than 23.82% and 20.13% respectively, significantly lower than the regional CO₂ emission growth, which are 47.92% and 86.62%. That is to say, the power industry has made great contribution to CO₂ emission reduction. Meanwhile, the results show that the developed model can meet the management target of maximizing the reduction of power CO₂ emissions, under the premise of regional economic development and energy requirements, which can provide reasonable reference to the administrative department.

**REFERENCES**


[10] The notice of ministry of science and technology about printing and distributing "twelfth five-year" national carbon capture use and storage technology development special planning [EB/OL]. [2013-03-11].