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Analysis of energy storage operation and configuration of high proportion wind power system

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Abstract: *Driven by the goal of "carbon neutrality", the future power system will be a high proportion of renewable energy power system. This paper takes a high proportion of wind power system as an example to explore the influence of "supply side" low-carbon transition on the economy and reliability of power system operation.In this paper, a nonlinear model can be established based on the need of investment cost and operation and maintenance cost to the daily total output value of total load power and energy storage cost, so as to obtain the minimum daily output data of three units, and draw the daily power generation curve of the unit according to the relationship between the three units and the lowest cost.Secondly, the balance of the system power is analyzed and the cost of wind power is calculated.*

Keywords: *linear programming model; Generating capacity of unit; Wind power installation efficiency; Abandon air volume*

1. Introduction

With the introduction of carbon neutrality, carbon peak and other related plans, it means that China has opened a new chapter in the stage of ecological construction.In the power system, the supply capacity of "zero-carbon" power mainly based on some renewable energy sources, such as wind power, has been greatly improved. The correlation, randomness and volatility of wind power operation largely determine the real-time operation economy of the system[1].Therefore, it is very important to realize low cost and high power of energy storage balance system. Aiming at the calculation problem of the minimum cost of thermal power, this paper makes a model and solves the model, and runs with the minimum cost of power generation.[2]

2. Power balance model

2.1 Model establishment

There are three forms of energy conversion in the process of thermal power generation: chemical energy of fuel → steam heat energy → mechanical energy → electric energy. In other words, the fuel will generate heat energy in the combustion process and heat water into high temperature and high pressure water vapor. The water vapor drives the engine to generate mechanical energy and do work to achieve the purpose of power generation.Carbon capture technology in combustion generally refers to the enrichment of oxygen through air separation or oxygen carrier. When fossil energy is burned, oxygen and other gases are introduced to generate high concentration of carbon dioxide, so as to reduce the separation difficulty and energy consumption of carbon dioxide and inert gases in the air such as nitrogen.The system to be studied includes thermal power, wind power, energy storage and load. Assuming that there is no wind power access, thermal power operates at the minimum cost, i.e., the minimum value in the table is used for both[3], and the unit power supply cost of the system = the total power generation cost of the system/the total load quantity of the system, i.e$S_1 S_2 S_3$

$$E = \frac{G_{all}}{Y_{total\ load\ electricity}} \tag{1}$$

Thermal power cost includes operation cost and carbon capture cost, wherein the operation cost of thermal power consists of operation and maintenance cost and power generation coal consumption cost. Given that the price of thermal coal is 700 yuan /t, the operation cost of thermal power can be obtained according to the relationship between coal consumption and power generation output[4]

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$$G_{run} = 700 \cdot F + 0.5 \cdot 700 \cdot F = 1050F \tag{2}$$

The cost of carbon capture refers to the purification of carbon dioxide and other carbon-containing compounds generated by combustion in the process of thermal power generation, and then used in other production links to recycle carbon containing compounds that were originally polluting gases, improve utilization rate and reduce emissions. [5]

$$G_{\text{Carbon capture}} = Q_{\text{Power generation}} \times \delta_{\text{Carbon emission coefficient}} \times P_{\text{unit price}} \tag{3}$$

There are 3 thermal power units, and the thermal power cost is the sum of each thermal power unit:G_{run}与$G_{\text{Carbon capture}}$

$$G_{fire} = \sum_{i=1}^{3} G_{i\,fire} + \sum_{i=1}^{3} G_{iCarbon\ capture} \tag{4}$$

For the energy storage device, according to the definition given in the question, when calculating the daily cost, the investment cost should be amortized to every day. Once built, it can take ten years, so the cost of every day in ten years is.

(The investment cost consists of unit power cost and unit energy cost)

$$G_{investment} = \frac{3000}{10\times365} \times [\sum_{i=1}^{3} S_i + \sum_{i=1}^{3} Q_i] \tag{5}$$

Operation and maintenance cost of energy storage device

$$G_{operations} = 0.05 \times \sum_{i=1}^{3} Q_i \tag{6}$$

Therefore, the energy storage cost of the system is the sum of investment cost and operation and maintenance cost, i.e

$$G_{Energy\ storage} = \frac{3000}{10\times365} \times [\sum_{i=1}^{3} S_i + \sum_{i=1}^{3} Q_i] + 0.05 \times \sum_{i=1}^{3} Q_i \tag{7}$$

The maximum load power of the system is 900MW

$$\sum_{i=1}^{3} Q_i \le 900MW \tag{8}$$

Therefore, the energy produced by the system in a day under one condition is

$$Y_{\text{total load electricity}} = \sum_{i=1}^{3} Q_i \tag{9}$$

2.2 Solving the model

The daily generation planning curve of the unit is obtained after solving, as shown in Figure 1.

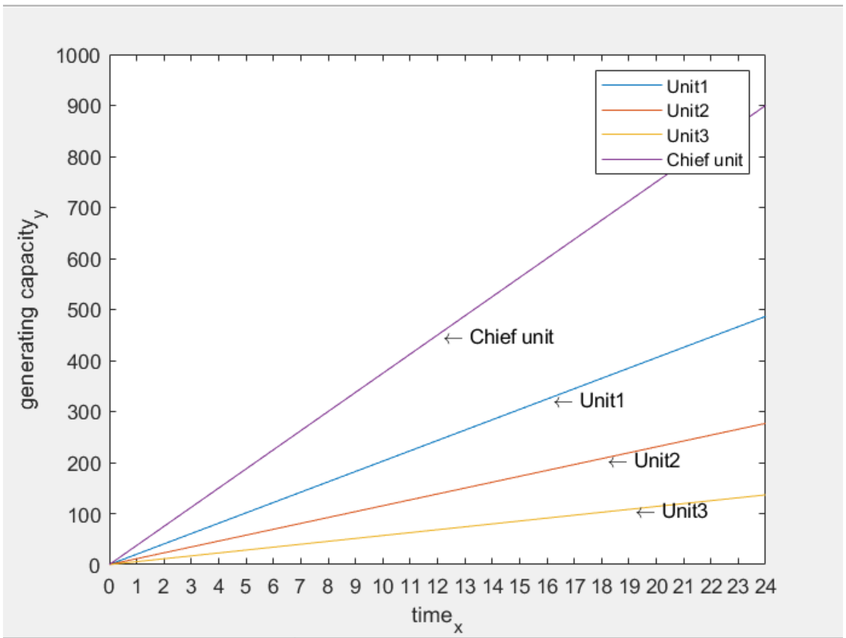

Figure 1: Daily generation planning curve of unit

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MATLAB was used to program and calculate the above model, and the results are shown in Table 1.

Table 1: System related indicators statistics when the proportion of wind power is 0

Carbon capture cost (Yuan /t)	Thermal power operation Cost (ten thousand yuan)	Carbon capture cost (ten thousand yuan)	Total Generation Cost (ten thousand yuan)	Unit power supply Cost (ten thousand yuan)
0	3.53	0	3.61	0.00400
60	3.53	0.00400	3.61	0.00400
80	3.53	0.00530	3.61	0.00400
100	3.53	0.00660	3.61	0.00400

3. Power balance analysis of the system

In the process of wind power generation, there are two energy transformations: wind energy → mechanical energy → electric energy. That is, wind power is used to drive the blades of windmill to rotate, and then the speed of rotation is increased through the speed increaser to promote the generator to generate electricity.In this process, there is no need to burn chemical fuels, so there is no air pollution or radiation.The system to be studied includes thermal power, wind power, energy storage and load. In the second question, when the installed wind power is 300MW and the replacement unit is 2, the installed capacity and maximum load power of the system will change, which will affect the balance, because wind power permeability = the ratio of maximum wind power to maximum load power, i.e

$$\alpha = \frac{\rho installed}{Ytotal\ load} \quad (10)$$

Through the data of wind power and load normalized power in a certain day, the original actual wind power value can be restored, so as to determine the specific wind abandoning duration and wind abandoning quantity, and record it every 15 minutes to obtain the actual permeability of dynamic wind power $\alpha_{1,\ t}$

$$\alpha_{1,\ t} = \frac{\rho Wind\ power}{Ytotal\ load} \quad (11)$$

when $\alpha_{1,\ t} \leq$, that is, the actual wind power permeability is less than the theoretical wind power permeability, the wind power permeability meets the power generation requirements, and the wind power is in load loss; α

when $\alpha_{1,\ t} \geqq \alpha$, that is, the current actual wind power permeability is greater than the theoretical wind power permeability, the wind power permeability does not meet the power generation requirements, the power generation of the wind power system is greater than the demand, and the wind power system is in load abandonment;

$$\alpha = \sum_{n=1}^{98} \beta_n Y_n load \triangle t \quad (12)$$

β_n=0 when the actual wind power permeability $\alpha_{1,\ t} \leqq$ theoretical wind power permeability α

β_n=1 when the actual wind power permeability $\alpha_{1,\ t} \geqq$ theoretical wind power permeability α

$$\alpha = 900 - \sum_{n=1}^{98} \beta_n Y_n load \triangle t\text{-}Q_1 - Q_2 \quad (13)$$

Among them $\overline{\beta_n}$ for β_n The not;

If you reduce wind capacity to R

There are $=P_{installed}^{*} P_{installed} - R$

Let R=n*step, where step is the step size

Solve the Q corresponding to n and calculate the n corresponding to the minimum value is the solution of the problem. When 300MW wind power is replaced, the power balance of the system can be reduced by 11.22%.

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4. Wind power cost calculation

Through the system power balance model and system power balance analysis, get the corresponding parameters to default value of this problem, problem to define: the total cost = thermal power generation cost + cost of wind power, energy storage, abandon the wind loss and load loss, including thermal power cost and storage cost, already solved , wind power costs for load and loss.Table 2 shows the statistics of system related indicators when 300MW wind power unit is replaced by unit 3.

Table 2: System related index statistics when 300MW wind turbine is replaced by unit 3

Carbon capture cost (Yuan /t)	Thermal power unit transport Bank cost/ten thousand yuan	Carbon capture costs / ten thousand yuan	Wind power operation and maintenance costs / ten thousand yuan	Abandon the wind loss		Loss of load		Unit power supply Cost (ten thousand yuan)
				Abandon the wind power /MWh	Abandon the wind loss / ten thousand yuan	Lost load quantity /MWh	Loss of load / ten thousand yuan	
0	2.5893	0	0.0013	30.7322	9.2197×10^{-4}	343.9127	0.2751	32.7572
60	2.5893	0.0031	9.3321×10^{-4}	30.7322	9.2197×10^{-4}	418.9451	0.3352	33.4545
80	2.5893	0.0043	0.0013	30.7322	9.2197×10^{-4}	380.9151	0.3047	33.1352
100	2.5893	0.0056	0.0013	30.7322	9.2197×10^{-4}	381.3061	0.3050	33.1517

Table 3 shows the statistics of system related indexes when the 600MW wind power unit is replaced by 2 units.

Table 3: statistics of system related indexes when 600MW wind power generating unit is replaced by 2

Carbon capture cost (Yuan /t)	Thermal power unit transport Bank cost/ten thousand yuan	Carbon capture costs / ten thousand yuan	Wind power operation and maintenance costs / ten thousand yuan	Abandon the wind loss		Loss of load		Unit power supply Cost (ten thousand yuan)
				Abandon the wind power /MWh	Abandon the wind loss / ten thousand yuan	Lost load quantity /MWh	Loss of load / ten thousand yuan	
0	2.3631	0	0.0023	30.7322	9.2197×10^{-4}	496.1592	0.3969	31.6091
60	2.3631	0.0024	0.0016	30.7322	9.2197×10^{-4}	492.0884	0.3937	31.5916
80	2.3631	0.0024	0.0022	30.7322	9.2197×10^{-4}	496.1592	0.3969	31.6349
100	2.3631	0.0032	0.0021	30.7322	9.2197×10^{-4}	496.1592	0.3969	31.6424

5. Conclusion

This paper takes a high proportion of wind power system as an example to explore the influence of "supply side" low-carbon transformation on the operation economy and reliability of power system.First clear fire motor output linearly proportional relationship with coal consumption, the system total load power and energy storage cost in the cost of investment, operational cost for output to the need of numerical value, nonlinear model is established, which can get three nissan lowest unit data, according to the connection between the three unit capacity and the lowest cost to map the unit power curve.

Second through the normalized value of the load power and wind power, the ideal state of wind power penetration for four thirds, but the actual wind power penetration to the actual wind power penetration/actual load power, which can determine what time to abandon the wind, when actual permeability > the theoretical value, its judgment, again through the unit conversion, it is concluded that the moment of air volume.Finally, the calculation of carbon capture cost is carried out, and the optimal power generation value is obtained through linear programming.And complete the statistics of system related indicators.

References

[1] Markovics Dávid, Mayer Martin János. Comparison of machine learning methods for photovoltaic power forecasting based on numerical weather prediction[J]. Renewable and Sustainable Energy

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Reviews,2022,161.
[2] Pierro Marco, Gentili Damiano, Liolli Fabio Romano, Cornaro Cristina, Moser David, Betti Alessandro, Moschella Michela, Collino Elena, Ronzio Dario, van der Meer Dennis. Progress in regional PV power forecasting: A sensitivity analysis on the Italian case study[J]. Renewable Energy,2022,189.
[3] Al-qaness Mohammed A.A., Ewees Ahmed A., Fan Hong, Abualigah Laith, Elaziz Mohamed Abd. Boosted ANFIS model using augmented marine predator algorithm with mutation operators for wind power forecasting[J]. Applied Energy,2022,314.
[4] Ratshilengo Mamphaga, Sigauke Caston, Bere Alphonce. Short-Term Solar Power Forecasting Using Genetic Algorithms: An Application Using South African Data [J]. Applied Sciences, 2021,11(9).
[5] Alkabbani Hanin, Ahmadian Ali, Zhu Qinqin, Elkamel Ali. Machine Learning and Metaheuristic Methods for Renewable Power Forecasting: A Recent Review [J]. Frontiers in Chemical Engineering,2021.