The optimization of power transaction model with electricity market reform

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Abstract: With the specification of electricity trading market, to strengthen electric power demand side management, improve the mechanism of electric power emergency and establish a long-term mechanism, this paper proposed the monthly power generation planning optimization model based on the grey model algorithm. The paper studied the regional power grid dispatching management, according to the market and the development direction of energy conservation. This method paid attention to monthly free energy conservation strategy, meanwhile, improved the rate of short-term energy saving establishment. The optimized energy-saving power generation establishment can be more comprehensive for resource allocation and scheduling in the power generation scheduling, and to better meet the needs of the electric power market reform.

1. Introduction

With the deepening of energy-saving and emission-reduction of power grids, the improvement of grid power generation planning has become a key link in the energy-saving and emission reduction of the power industry. At this stage, the main method of domestic energy-saving power generation dispatch is the energy-saving scheduling algorithm according to the energy consumption ranking, under the existing power grid operating conditions, the short-term power generation plan of the unit is optimized. However, from the laws and practical operation of energy-saving power generation dispatching, create and optimize a monthly energy-saving power generation dispatch model, combining the trends of new energy development and utilization, can achieve better scheduling results\textsuperscript{[1]}. Energy-saving power generation dispatch is essentially a unit combination problem. At present, domestic and foreign research results for short-term daily power generation plans and long-term annual energy plans are relatively rich\textsuperscript{[2-4]}. Many scholars have proposed different power generation scheduling power generation model\textsuperscript{[5-7]}. In order to effectively solve the short-term nature and limitations of current energy-saving power generation dispatching work, this paper designs a monthly dispatching model for energy-saving power generation. This model takes the safe operation of power grids as a precondition, and studies coal-fired power consumption measurement technologies to fully consider the double optimization goals of “energy saving” and “emission reduction” achieves the optimal allocation of power resources within the monthly span. Simultaneously, it also improves the energy-saving and emission-reduction effects of the power generation plan.
2. Monthly power generation planning model based on grey model prediction algorithm

The core of the monthly power generation plan is to achieve the balance of power supply and demand in the coming months\cite{8}. Because of the bias and uncertainty in monthly forecasts, the key is to achieve a wider range of resource optimization through the adjustment of various types of plans. The monthly plan should be based on the forecast of monthly electricity demand, the cost of electricity purchase within and outside the region, and the overhaul plan for power generation and transmission, to coordinate the power generation resources from the perspective of controlling the future operation risk of the power grid, and achieve safe, economic, and clean dispatch operation of the power grid\cite{9, 10}; Optimize the functions of each functional module of the entire dispatching power generation plan and the coordinated operation mechanism between each other, to ensure the orderliness, safety, and stability of the entire power grid dispatching plan from long-term to short-term; Since the monthly electricity purchase can have enough time to purchase electricity in and out of the region, it is determined that the monthly space has greater optimization space than before and in real time\cite{11}. To this end, it is necessary to combine various fuel plans, maintenance plans, and incoming water plans to optimize the entire grid’s dispatching and operation process from a wider scope and improve the economic efficiency of the grid.

Based on the dynamic closed-loop feedback coordination mechanism\cite{12-15}, according to the actual operating data of the power grid, the deviation between the predicted load and the actual load is fed back to the load forecasting module, and the load forecasting curve is corrected in time, which can improve the accuracy of the forecast; Through data mining, pattern recognition and other technologies, the key blocking lines and the active cross-section constraint information are fed back to the daily power generation planning optimization model and the monthly unit combination optimization model, which makes the unit’s start-stop plan and output curve more executable than the actual topology of the grid.

In this paper, the gray model prediction algorithm\cite{16, 17} is used to optimize monthly power generation planning, an exponential smoothing algorithm, and a sliding average algorithm. Combining various algorithms with different advantages and disadvantages, the gray model checking algorithm of GM (1, 1) is adopted. The series accumulation enhances regularity while weakening randomness. The algorithmic process is as follows:

\[
    x^{(n)} = [x^{(n-1)} | k = 1, 2, ..., n] \quad (n = 0, 1) \quad (1)
\]

\[
    x^{(n)}(k) = \sum_{i=1}^{k} x^{(n-1)}(i) \quad (2)
\]

Calculate array matrix \( A \) and data vector \( B \):

\[
    A = \begin{bmatrix}
        -1/2 [x^{(1)}(1) + x^{(1)}(2)] & 1 \\
        -1/2 [x^{(2)}(2) + x^{(2)}(3)] & 1 \\
        \vdots & \vdots \\
        -1/2 [x^{(n-1)}(n-1) + x^{(n-1)}(n)] & 1 
    \end{bmatrix}
\]

(3)
Calculate gray model parameters $\hat{\alpha}$ and $\hat{u}$,

$$\hat{C} = \begin{bmatrix} \hat{\alpha} \\ \hat{u} \end{bmatrix} = (A^T A)^{-1} A^T B_n$$

Finally establish a gray prediction model:

$$x^{(1)}(k+1) = x^{(0)}(1) - \frac{u}{\alpha} e^{-ak} + \frac{u}{a}$$

The optimization of the monthly unit start-stop plan using the objective function of the traditional unit combination model:

$$\min \sum_{t=1}^{T} \sum_{i=1}^{N} f^{\alpha}(P_i)$$

Where $T$ is the total number of time periods considered, $N$ is the total number of units, and $f^{\alpha}(P_i)$ is a function of the overall characteristics of the unit.

After determining the power balance situation in each month, the monthly unit combination scheme obtains system power supply surplus capacity by reasonably determining system reserve capacity. The units with higher energy consumption are selected to be shut down for backup within a certain period of time to achieve the optimization of the start-stop plan for monthly units. It is necessary to comprehensively consider the monthly maintenance schedule of the unit, the upper and lower limits of the unit output, the minimum continuous operation/downtime of the unit and other practical operational constraints to ensure the rationality of the startup plan. Its improved composite model objective function is:

$$\min \sum_{t=1}^{T} \sum_{i=1}^{N} \left[ a_i f^{\alpha}(P_i) + S_{i,t,u} \right]$$

Where $a_i$ is the starting and stopping status of unit $i$ in $t$ period, and $S_{i,t,u}$ is the coal consumption started by the unit. The unit's integrated characteristic function is its load-coal consumption characteristic function.

3. Optimization Simulation Study

Taking the monthly energy consumption as an example, the actual dispatching model and the balanced dispatching model based on the monthly average load ratio, and considering the start-stop status of the unit, the unit load rate, and the average coal consumption of the coal-fired units in the grid, the monthly schedule optimization described in this paper is simulated and analyzed.

Based on the existing coal consumption data of a provincial power company, a quantitative simulation study was conducted on conventional generator sets. The initial research object is two sets of main generating units with a capacity of 600MW and 1000MW, and two sets of small standby
generator sets with a capacity of 200MW and 300MW. The quadratic curve fitting formula for the load-coal characteristics data is:

\[ H = aP^2 + bP + c \]  \hspace{1cm} (9)

Its parameters are shown in Table 1.

**Table 1. Parameter list of load in simulative set - coal consumption in curve of the second degree**

| Simulation unit | Load - coal consumption parameters \( (H = aP^2 + bP + c) \) |
|-----------------|-------------------------------------------------------------|
|                 | a              | b              | c              |
| unit 600MW1     | 0.0000169     | 0.27601        | 11.46196       |
| unit 600MW2     | 0.0000234     | 0.28703        | -6.9181        |
| unit 1000MW1    | 0.0000197     | 0.23338        | 32.0851        |
| unit 1000MW2    | 0.0000247     | 0.45861        | 19.9188        |
| unit 200MW1     | 0.0000988     | 0.23333        | 13.9513        |
| unit 300MW1     | 0.0001375     | 0.33394        | -6.8571        |

Simulate the data in Table 1 and simplify calculations, it can be introduced that in practice, the average load factor of the 1000MW unit is slightly higher than that of the equalized dispatch model, which is almost full. The peak pressure of the system is borne by the remaining small capacity units, and the advantages of low energy consumption of large units have been fully utilized. In the three dispatch modes, the 1000MW unit is turned on for the whole month. The average load rate of the 600MW unit is low every day, which is equivalent to the average load rate of the 1000MW unit; in the actual dispatching mode, the average load factor of the unit is slightly higher than that of the equalized dispatch model; In the optimal scheduling mode, the load factor of the 600 MW class unit has been greatly improved, but due to the system's certain peak pressure, the average load rate is slightly lower than the 1000MW unit. In the three dispatch modes, the 600MW unit is on for the whole month. The experimental results for the simulation data are shown in Table 2.

**Table 2. Average coal consumption rate of three dispatch modes in simulative condition**

| model                  | Total coal consumption (10kt) | Average coal consumption (g/kWh) | Total coal saving (10kt) | Coal savings per unit (g/kWh) | Coal saving rate |
|------------------------|--------------------------------|----------------------------------|--------------------------|-----------------------------|-----------------|
| Balanced scheduling    | 545.2                          | 311.09                           | --                       | --                          | --              |
| Actual scheduling      | 538.9                          | 307.51                           | 6.3                      | 3.58                        | 1.15%           |
| Improved scheduling    | 521.0                          | 297.25                           | 24.2                     | 13.84                       | 4.45%           |

In the balanced dispatch mode, the utilization level of each level of the unit is quite similar, but the energy saving of the grid is reduced due to the pursuit of the balance of power generation. The average coal consumption of the grid in this mode is the highest, reaching 311.09g/kWh; in the actual dispatch mode, the start-stop condition of the unit is not optimized, but the load factor of the start-up unit is adjusted accordingly. The load rate of large units is higher than that of small ones. In this model, the average coal consumption of the power grid is 307.51g/kWh, and the coal saving rate reaches 1.15%; in the optimal dispatching mode, the peak load pressure of the system is assumed by the small units, and the large 1000MW unit is fully utilized. The entire month is almost full, and the small
capacity unit is used as an outage in the system most of the time, and the utilization rate is greatly reduced. The average coal consumption of the grid in this model is 297.25g/kWh, which is 4.45% compared to the balanced coal consumption rate. The energy-saving potential of the power grid has been fully utilized.

4. conclusion

Based on the analysis of current monthly energy-saving generation scheduling, this paper proposes a monthly power generation planning optimization model based on the grey model prediction algorithm. According to the monthly load forecasting, transmission and transmission equipment maintenance plan, taking into account the balance of power supply and demand, system standby and future grid operation risks and grid critical section constraints, this article optimizes the decision-making monthly shutdown unit plan. Improve the orderliness of energy-saving power generation dispatch, help optimize the progress of the contractor's contracted power generation, and avoid frequent start-stop; improve the effectiveness of energy-saving power generation dispatch and realize mutual cooperation among large-scale units of the same type. Through orderly mediation between the units, the operating load rate of the unit is greatly increased, and the total power generation coal consumption of the system is reduced. It is of positive significance to reduce coal consumption and promote energy conservation by using actual coal consumption instead of design coal consumption that is out of line with the actual situation, and to improve the fairness under conditions of energy-saving generation dispatch. The use of measured coal consumption instead of the design coal consumption that is out of line with the actual situation to sort, reduce coal consumption, and promote energy conservation has positive significance and improves the fairness under energy-saving power generation dispatching conditions.

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