The Rolling Optimization Method for Medium and Long Term Contract Plan Taking into Account Dispatching Progress

Zhenyu Ren[1], Xuan Li[1], Feng Liu[2], Mengli Zhao[2], and Fengjiao Xu[2](✉)

[1] Inner Mongolia Power (Group) Co., Ltd Hohehot, Inner Mongolia Autonomous Region, 010000 Hohehot, China
[2] Beijing Tsintergy Technology Co. Ltd., 100084 Beijing, China
xufj@tsintergy.com

Abstract. The annual contract decomposition and monthly contract rolling plan is one of the core businesses in the power grid dispatching department. The scientific and reasonable rolling decomposition of contract is not only an important guarantee for the economic operation of the power system, but also provides a space for the smooth trading of electric power and the maximization of renewable energy consumption. In this paper, we propose a rolling adjustment method for medium and long-term contract plan taking into account the deviations of the dispatching progress. This method is based on the equilibrium progress decomposition strategy for annual contract. Then we construct a rolling correction mathematical model while satisfying the requirement for deviation between the monthly cumulative power generation progress and the overall progress. It has achieved optimal adjustment of the medium and long-term contract plan and the generation scheduling of each thermal power plant, while ensuring the full consumption of renewable energy. Finally, taking the data provided by the provincial power grid as an example, the validity of the model is verified by the solution method of linear programming.

Keywords: Power Generation Plan · Security Constraints · Contract Decomposition · Linear Programming · Power Dispatch

1 Introduction

Annual contract decomposition and scheduling is one of the core businesses of the power grid dispatching department, the quality of this work will have an impact on the actual power generation progress and dispatching adjustment. In the decomposition process, the annual contract of all power plants in the region needs to be decomposed into the monthly contract. However, with the monthly forecast load, seasonal hydropower resources, uncertainty renewable energy, fault maintenance and other factors changing during the actual operation, there may be a large monthly deviations between the actual power generation and the decomposed contract in [1], which will make it difficult for the dispatching department to adjust the plan of remaining monthly contract, the original

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annual decomposed contract will not be executed smoothly as well. Therefore, it is of great significance to study a balanced and reasonable annual contract decomposition model and method, and to achieve scientific scheduling of the power generation plan in subsequent months based on actual power generation.

There have been a lot of studies on the decomposition and rolling compilation of daily contract [3, 4, 5, 8], while there are relatively few studies on the medium and long term contract decomposition. In terms of contract decomposition, [6] proposes a generic annual and monthly contract decomposition model, based on the equilibrium progress factor and taking into account the overall progress balance of each power generation unit through a segment-by-segment decomposition method; [2] proposes a deterministic contract decomposition method applicable to Zhejiang power grid, which directly composes the annual contract to each power plant in each period. In [7], a rolling correction model based on the load-rate balance of the contract is proposed to ensure that the year-end power generation units have a reasonable adjustment space; in [9], a contract rolling compilation method is composed to determine whether the deviation of the current month's contract execution meets the adjustable power margin for the following month. However, the above studies do not fully consider the scheduling and control needs of the dispatching department in the long time scale, the weighting preferences in the medium and long term are also ignored.

Based on the equilibrium progress decomposition strategy for annual contract, this paper proposes a rolling adjustment method and stablishes a rolling correction model for medium and long term contract planning which takes into account deviations in the schedule and control progress. The method optimizes and adjusts the monthly power generation plan of each power plant in the region, while satisfying the requirement for deviations between the monthly contract power planning progress and the regulation progress. This paper uses an algorithm of solving the linear planning to verify the validity of the model which data provided by a provincial power grid company. Considering that the contract for renewable energy in the provincial power grid is made separately mainly based on hydropower resources, meteorology and local policies, the medium and long term contract decompos-optimization problem in this paper is only for the thermal power plants, which ensures the priority consumption of renewable energy such as PV and wind power and helps the dispatching department to realize the scientific contract scheduling.

2 Mathematical Model and Algorithm for the Rolling Decomposition of Medium and Long Term Contract

2.1 Concept of Balanced Progress Taking into Account Dispatching Progress

The equilibrium of power contract execution is reflected in the process equilibrium and the result equilibrium. The process equilibrium emphasizes that in the execution process of the power contract, the specific execution process of each power plant is reasonable in time and space progress, and the result equilibrium refers to the final completion rate of each power plant contract power is similar.

This paper first proposes a setting method based on the equilibrium progress – the average progress of the whole grid considering dispatching progress correction.

First, the average progress of generation in month m is defined as

$$H_{GAP}^{(m)} = \frac{\sum_{m'=1}^{m} Q_G^{(m')}}{Q_G^Y} \tag{1}$$

$Q_G^{(m)}$ is the cumulative contract for month m in grid; Q_G^Y is the total contract for the whole year. Using the average progress of the whole grid as the equilibrium progress indicates that the dispatching department is concerned about the consistency of the overall contractual execution progress of the power plant from month to month, which is easy to understand simply and intuitively. However, it ignores the accumulation of progress deviations due to uncertainties factors affecting in the medium and long term process.

On the basis of $H_{GAP}^{(m)}$ and the dispatching progress correction, define the average progress of plant I in month m as

$$H_{CMGAP,i}^{(m)} = \frac{\sum_{m'=1}^{m} Q_G^{(m')}}{Q_G^Y} .W_{contr} \tag{2}$$

W_{contr} is the dispatch progress correction factor, which reflects the dispatch progress weighting given by dispatch department based on the overall generation progress in execution. On the one hand, the dispatching department consider the medium and long term uncertainties in the power generation unit, adjusts the monthly planned target based on the deviation of the actual power generation progress,ensure that the following monthly planned schedule is maintained, reduced or accelerated in the process; On the other hand, the dispatching department expects each power plant to complete the contract schedule at the same ratio in the end of the year, i.e. to meet the optimization target of the annual plan completion rate. Therefore, appropriate adjustments to the equilibrium progress can be made to satisfy dispatch's control of the contract completion progress.

2.2 Objective Function

$$Min\sum_{m=T_m}^{T_M}\sum_{i=1}^{N_P}\left|\rho_{P_i}^{m} - H_{CMGAP,i}^{(m)}\right| \tag{3}$$

T_m is the month in which rolling decomposition starts; T_M is the month in which rolling decomposition ends, and the default value T_M=12; N_P is the total number of power plants in the region, and $\rho_{P_i}^m$ represents the cumulative contract progress of power plant I in month m *as expressed below.*

$$\rho_{P_i}^{m} = \frac{\sum_{m'=1}^{m} Q_{P_i}^{m'}}{Q_{P_i}^{Y}} \tag{4}$$

For months that have occurred, $Q_{P_i}^m$ is the plant's actual monthly executional contract as a known quantity; for months that have not occurred, $Q_{P_i}^m$ is the plant's scheduled contract as a decision variable; and $Q_{P_i}^Y$ is the plant's annual contract. $H_{CMGAP,i}^{(m)}$ is the average progress of plant on the basie of dispatching progress correction, which is defined in Sect. 2.1.

2.3 Constraints

2.3.1 Electricity Supply-Demand Balanced Constraints

The objective function needs to ensure the balance of electricity power on a monthly basis, taking into account factors such as network losses, power generation from self-owned power plants and renewable energy consumtion, to ensure that the sum of power generation and network losses in the region is in balance with the load demand for electricity.

$$\sum\nolimits_{i=1}^{N_P} Q_{p_i}^m + Q_S^m + Q_R^m + Q_T^m + \sum\nolimits_{j=1}^{N_X} \left(1 - \beta_{X_j}^m\right) Q_{X_j}^m = Q_D^m + Q_{X_L}^m \tag{5}$$

N_X is the total number of external contact lines j, $\beta_{X_j}^m$ is the network loss coefficient of external contact lines, obtained from statistical data estimation; Q_S^m is the planned electricity of captive power plants, Q_R^m is the forecast electricity of renewable energy sources, Q_T^m is the monthly planned trade electricity, provided by the statistics of dispatch and generation departments, and Q_D^m is the monthly load demand electricity in the region, estimated by the respective power supply bureau; $Q_{X_L}^m$ is the loss of electricity consumption in the regional grid.

2.3.2 Constraints of Grid Safety

$$\sum\nolimits_{i=\Omega_k}^{N_P} d_{P_i,\Omega_k} Q_{p_i}^m \le \overline{Q}_{\Omega_k}^m \tag{6}$$

Ω_k represents the set of grid safety constraints. Considering the energy transfer distribution factor d_{P_i,Ω_k} for power plant I, the left formula finds the energy distribution for each power plant device under failure. $\overline{Q}_{\Omega_k}^m$ represents the upper limit of the network security energy.

It should be noted that a more accurate representation of these constraints should be in the form of electricity, but in practical decision making, there are many difficulties in using the electricity form, so it is approximated by electricity.

2.3.3 Constraints of Coal Storage Capacity

A power plant's total monthly coal consumption shall be less than or equal to the plant's coal storage capacity for the month.

$$Q_{p_i}^m h_{p_i}^m \le S_{P_i} T_M \tag{7}$$

$h_{p_i}^m$ is the unit coal consumption of power plant I, and S_{P_i} is the coal stored of power plant I in current month.

2.3.4 Constraints of Power Plant Capacity and Load Ratio

$$
\begin{aligned}
&C_{P_i}^{m} = \sum\nolimits_{j=1}^{G_{P_i}} \left(1 - \frac{D_{P_i,G_{j,}}^{m}}{T_D^{m}}\right) C_{P_{i,}G_j} \\
&M_{P_i}^{m} C_{P_i}^{m} T_D^{m}.24
\end{aligned} \tag{8}
$$

$C_{P_i}^{m}$ is the adjustable capacity of the power plant *I* in month *m*, $M_{P_i}^{m}$ is the maximum generating capacity of the power plant *I* in month *m*. The adjustable capacity of power plants is determined on the basis of generating unit capacity and monthly maintenance schedule.

G_{P_i} is the total number of units j in plant I, $\mathrm{D}_{\mathrm{P_{i,}G_{j,}}}^{\mathrm{m}}$ is the number of maintenance days in month *m* for unit *j* in plant *I*, T_D^{m} is the total number of days in month *m*, $C_{P_{i,}G_{j,}}$ is the adjustable unit capacity for unit *j* in plant *i*.

In actual operation, due to a variety of factors such as system reserve capacity, heating capacity, unscheduled outages, and plant load ratio constraints, it is often necessary to specify a range of variation in the power plant's generation capacity, which is typically achieved by specifying a unit power generation or power plant load rate range.

$$
\begin{aligned}
&\underline{Q}_{p_i}^{m} \le Q_{p_i}^{m} \le \bar{Q}_{p_i}^{m} \\
&\underline{R} \le R_{p_i}^{m} \le \bar{R} \\
&R_{p_i}^{m} = \frac{Q_{p_i}^{m} + Q_{T_i}^{m}}{T_H . D_{P_i}^{m} . C_{P_i}^{m}}
\end{aligned} \tag{9}
$$

In the above equation, $\underline{Q}_{p_i}^{m}$ and $\overline{Q}_{p_i}^{m}$ are the lower and upper limits of the power generation considerating the operating constraints of the power plant. $\underline{R}$ and $\overline{R}$ are the upper and lower limits of the load ratio. $R_{p_i}^{m}$ is the load ratio of the power plant *I* in month *m*, and $Q_{T_i}^{m}$ is the planned trading electricity of plant *I* at the beginning of month *m*.

2.3.5 Constraints of Power Generation Plan

$$
\begin{aligned}
&\rho_{P_i}^{Y} = \rho_{P_i}^{m}|_{m=12} \\
&\left|\rho_{P_i}^{Y} - 100\%\right| \le \rho_{Mrg}
\end{aligned} \tag{10}
$$

During the plan making process, the department should allocate the contract reasonably with fully considering the ability of the power plant to complete the annual plan in the following months. Ensure that each power plant completes the annual power generation plan in a balanced way as far as possible. If the power generation plan at the beginning of the year is unreasonable, it is allowed to set the final deviation margin ρ_{Mrg}, and $\rho_{P_i}^{Y}$ represents the completion rate of the annual power generation plan, which is equivalent to the cumulative power generation plan progress of the power plant in December.

2.4 Algorithm

Referring to the approach of the absolute value planning technique for the objective function [12], non-negative auxiliary variables are introduced to transform the objective in the model into the following form.

$$\begin{aligned}
&\text{Min} \sum_{m=T_m}^{T_M} \sum_{i=1}^{N_P} \left(u_i^m + v_i^m\right) \\
&s.t.\ \rho_{P_i}^m - H_{CMGAP,i}^{(m)} + u_i^m - v_i^m = 0 \\
&\rho_{P_i}^m, u_i^m, v_i^m \geq 0
\end{aligned} \tag{11}$$

The special nonlinear planning problem containing absolute values is transformed into a linear planning problem, then can be chosen to be solved using advanced linear planning optimization tools such as CPLEX.

3 Algorithm Validation

A provincial power grid 2019 data is used to compile an algorithm example, and the effectiveness of the above model is verified by constructing an optimization model and relevant constraints and solving the algorithm using the CPLEX optimization software package. The algorithm example contains a total of 46 thermal power plants and decomposes the contract from April to December. The decomposition results are reasonable, effective and relatively friendly, meeting the requirements of the dispatching department for regulating the progress.

4 Conclusion

Considering the actual needs of dispatching departments for contract power decomposition and progress control of execution, this paper proposes a rolling decomposition optimization method for medium and long term power generation plan taking into account deviations in dispatching progress. The method can reasonably revise the annual power generation capacity decomposition and monthly power generation plan on the premise of the overall progress balance. It provides a sufficient space to adjust the progress during the execution of medium and long term contract, and helps the dispatching department to track and control the power generation plan on a longer time scale.

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