The Loss Reduction Research of Unit Power Optimizing with Considering Economic Benefit

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Abstract: Two primary approaches, which can reduce network loss and improve economic benefit of electric power system, are optimizing active and reactive power. This paper studies actual power network and puts forward a method which can reduce network loss through optimizing active power. And this method increases the constraint condition of power stations attribution. It changes the opening mode of units to divert electric quantity between different units. The relationship between the run mode of units and the change of loss electric quantity is found according to analyze the situation of network loss of different opening modes. The result indicates that the method can achieve the goal of reducing primary network loss by optimizing unit power in the same group. The economic benefits of various groups are not damaged at the same time.

1. Introduction
With the development of the society and the increasing growth of the science and technology, electric power industry has become the pillar industry of the countries in the world, which supplies necessary energy sources and power for the entire society. Because of the existing of impedances in the electric power system, electric energy transform, transport and distribute, there will be a mass of inevitable loss in the process of the transformation, transmission and distribution of electric energy. The loss is termed electric power system network loss. It is an important comprehensive index of technology and economy to judge operation condition of electric enterprises. The primary measures used to reduce network loss are optimizing active power and optimizing reactive power. The specific measures include optimizing power grid operation mode, enhancing power grid economic dispatching, accelerating the reform of power grids and strengthening management of line loss 1-3

2. Traditional methods of network loss reduction
Electric power network loss mainly consists of line loss, transformer loss, station using electricity loss and other loss. Station using electricity loss and other loss is 1.13% for all. Therefore, primary network loss in this paper means line loss \( \Delta A_L \) and transformer loss \( \Delta A_T \). The following formula comes from RMS current method:

\[
\Delta A = \Delta A_L + \Delta A_T = 3I_{\text{rms}}^2RT \times 10^{-3}
\]  

\( R \) in the formula means element resistance. \( T \) means operation time. \( I_{\text{rms}} \) means RMS current.

The common method of line loss calculation, which is used in traditional theoretical calculation, just uses several running data. For this reason, the error between theoretical calculation and practical
calculation is so large that it is difficult to realize line loss management effectively[4]. For advancing the accuracy of theoretical calculation, various modified algorithms that based on OPF method have become mainly research method to calculate network loss. The methods which apply OPF to change the unit power are easily influenced by network loss sharing scheme. For example, network loss factor (network correction factor) is built by network loss tiny-increasing-rate[5-7] to correct objective function, and then, be corrected by sharing network loss[8]. This kind of method is limited by accuracy of calculation and practical applicability.

At present the research of energy saving and consumption reducing is mainly concentrated on reducing network loss by management measure and increasing the reliability of power grid by optimizing reactive power, thereby reforming the structure of power grid. Literatures [9-12] study the method which can reduce network loss by analyzing operation mode of electricity market, perfecting the mould of electricity market and optimizing dispatching mode. Literatures [13-15] put forward the method which can reduce network loss by installing SVC, storing energy by capacitance and improving the structure of power grid. This paper takes the structure of power grid as entry point. It analyzes optimizing the unit power by how to change operation mode of power grid under the constraint condition of power stations attribution. Units power has been arranged reasonably based on the electricity sales of power generation grouped changed. This method considers economic benefit and adds the constraint condition of power plant attribution. It can make the economic benefit loss of each power generation group minimally. The aim of primary network loss reduced is achieved effectively.

3. The loss reduction method of unit power optimizing based on economic benefit

This paper doesn’t depend on theoretical calculation. It studies real power grid and puts forward a new method that could reduce network loss by optimizing unit power based on the structure of power grid and economic benefit. This method has been checked by simulation. The steps will be shown as follow. First, simulation data are adjusted and made sure the initial loss electric quantity in the simulation data, the same as the network loss data in the line loss monthly report. This step could confirm initial start-up mode of each power plant. Second, the influence rate of each power plant on network loss is confirmed. Third, the unit power transferring programs are built among different plants of the same group in all the power grid areas with constraints of the belonging group and power grid area of the plant. Fourth, the economic benefit of each program has been analyzed. Last, each program is simulated with electric power system simulation software of electric power system. The loss electric quantity of each scheme is gotten. The simulation results are compared with initial electric quantity, and then the regularity of optimizing unit power is found out.

If the problem of power plant attribution is not considered and the unit power is only changed, the economic benefit of power generation group will be affected. This paper adds constraint condition of power plant attribution to solve this problem. The benchmark price is calculated with 0.3723RMB/kWh. If group A transfers a hundred million kWh electric quantity to group B, it will loss 37.23 million RMB. So it is good for the groups to keep their economic benefit and achieve loss reduction by adding constraint condition of power plant attribution.

The study objects of each program are six kinds of running mode of goal grid including winter heavy load, winter medium load, winter low load, summer heavy load, summer medium load and summer low load. The situation of heating period and non-heating period is considered generally. The data can be handled by following formula:

$$Q_s = \frac{1}{2}Q_{ss} + \frac{1}{2}Q_{dss}$$

(2)

$Q_s$ means the rate of power-saving of one year. $Q_{ss}$ means the rate of power-saving in the situation of heating period. $Q_{dss}$ means the rate of power-saving in the situation of non-heating period.

$$Q_{ss} = \frac{7}{24}Q_{whs} + \frac{11}{24}Q_{wmu} + \frac{6}{24}Q_{wls}$$

(3)
\[ Q_{whs} \text{ means the rate of power-saving of winter heavy load. } Q_{wms} \text{ means the rate of power-saving of winter medium load. } Q_{wls} \text{ means the rate of power-saving of winter low load.} \]

\[ Q_{whs} = \frac{7}{24} Q_{sls} + \frac{11}{24} Q_{sms} + \frac{6}{24} Q_{shs} \]

4. The simulation test and the result analysis

4.1. The features of the aimed power grid structure

The aimed power grid is divided into four parts based on geographic location and running feature. They are eastern grid, middle grid, western grid and northern grid. Eastern grid is power source center which takes charge of delivering electric power. Middle grid is load center. Western grid and northern grid are major transmission passageway outside the province. There is no 220kV power plant in the northern grid. All the major power plants in the aimed power grid belong to the four power generation groups. Group H has eight power plants that are in the middle grid, eastern grid and western grid. Group T has five power plants which are in the middle grid and eastern grid. Group G has three power plants which are in the middle grid, eastern grid and western grid. Group N has four power plants which are in the eastern grid and western grid. It is shown in Figure 1.

![Diagram of aimed grid structure and power generation group attribution](image)

**Figure 1.** Aimed grid structure and power generation group attribution

4.2. The influence analysis between unit power and network loss

In order to confirm the best program of optimizing unit power under the constraint condition, following formula can be used to express the influence of unit power on loss. \( Q \) is power loss. \( Q_{ij} \) means generated energy of certain power plant in certain power group. \( i \) means the quantity of power groups and \( j \) means the quantity of power plants. \( \Delta Q_{ij} \) means the transferring quantity of power plant.

\[
\begin{aligned}
Q &= \frac{\partial Q}{\partial Q_{ij}} \\
\sum_{j=1}^{n} \Delta Q_{ij} &= 0 (i = 1, 2, \ldots, m)
\end{aligned}
\]

According to the simulation, we can see that power plants of large capacity have greater influence than others. Power plants in sending power grid have greater influence than others in power grid of local power balancing. So the star-up mode of eastern grid has the greatest influence in the aimed power grid. If we want to keep cross-section of eastern grid unchanged and reduce the network loss at
the same time. The start-up mode should be adjusted. In order to achieve the aim, large capacity and large influence units in middle grid and western grid should be closed when generated energy in eastern grid is increased. If program that transferring quantity from eastern grid to western grid and middle grid is arranged reasonably, network loss should be reduced. As shown in figure.2, figure.3, figure.4. Positive number means tendency of loss increase. Negative number means tendency of loss reduction.

![Figure 2](image2.png)  **Figure 2.** The influence of unit power in middle grid and eastern grid on loss

![Figure 3](image3.png)  **Figure 3.** The influence of unit power in grid eastern and western grid on loss

![Figure 4](image4.png)  **Figure 4.** The influence of unit power in western grid and middle grid on loss

Sampling dot 1 to 5 in figure.2 shows the situation of loss change that electric quantity is transferred from middle grid to eastern grid. Sampling dot 6 to 10 in figure.2 shows the situation of loss change that electric quantity is transferred from eastern grid to middle grid. Sampling dot 1 to 4 in figure.3 shows the situation of loss change that electric quantity is transferred from western grid to eastern grid. Sampling dot 5 to 8 in figure.3 shows the situation of loss change that electric quantity is transferred from eastern grid to western grid. Sampling dot 1 to 5 in figure.4 shows the situation of loss change that electric quantity is transferred from middle grid to western grid.

4.3. **Aimed grid simulation and analysis**

4.3.1. **Economic benefit level analysis.** The comparison and analysis of transferring electric quantity have been done between the same group and different groups in aimed grid. As in figure.5 the result shows eight start-up mode of power plant and loss condition. Mode 1 is initial start-up mode and initial network loss. Mode 2 shows that network loss reduces 6.14% when Group T transfers 401.50 million kWh to Group N, but Group T loss 95.1226 million RMB. Mode 3 shows that network loss reduces 4.32% when the same electric quantity as mode 2 is transferred among the Group T. Mode 4 shows that network loss reduces 2.77% when Group N transfers 401.50 million kWh to Group H, but Group N loss 95.1226 million RMB. Mode 5 shows that network loss reduces 4.06% when the same electric quantity as mode 2 is transferred among the Group N. Mode 6 shows that network loss reduces 2.63% when Group H transfers 401.50 million kWh to Group T, but Group H loss 95.1226 million RMB. Mode 7 shows that network loss reduces 0.36% when the same electric quantity as mode 2 is
transferred among the Group H. Mode 8 shows that network loss reduces 3.05% when Group G transfers 602.25 million kWh to Group H, but Group N loss 142.684 million RMB. Mode 9 shows that network loss reduces 2.12% when the same electric quantity as mode 2 is transferred among the Group G.

**Figure 5.** Unit power change and corresponding network loss of four power generation group

Through comparison and analysis of simulation we can see that loss reduction could be achieved through optimizing unit power between the same power generation group and different groups. When electric quantity is transferred, network loss will be reduced more in the different groups than that in the same group, however, it will make some power generation groups loss income. That is why, on consideration of economic benefit principle, the constraint condition of power plant attribution should be added when unit power is optimized.

#### 4.3.2. The influence of electric quantity on network loss in the same area

Unit power is adjusted and the change of loss quantity situation is analyzed in the same area of aimed grid under the condition of power plant attribution. As shown in Table 1, positive numbers mean electric quantity transfer in, and negative numbers mean electric quantity transfer out.

**Table 1.** Unit power transfer and loss quantity in the same area

| Program | Power plant | Transfer quantity /MWh | Annual saving /MWh | Attribution |
|---------|-------------|------------------------|-------------------|-------------|
| Eastern grid | H1B | -354050 | 5623.4 | H |
|          | H2B | 354050 |             |             |
|          | T1  | -501875 | -122.7 | T |
|          | T2  | 501875 |             |             |
|          | T3  | -766500 | 16965.1 | T |
|          | T4  | 766500 |             |             |
| Middle grid | H5B | -501875 | 10427.9 | T |
|          | H5A | 501875 |             |             |
|          | H6  | -438000 | 16825.8 | N |

According to the simulation results, we can see that the largest capacity H5 power plant has the largest influence on network loss in the middle grid. When 680 million kWh electric quantity is transferred from H5B plant to H6 plant, 5.46 million kWh electric quantity is saved in the middle grid. In the western grid, when 700 million kWh electric quantity is transferred from H3 plant to H4 plant, 1.15 million kWh electric quantity is saved. And when 520 million kWh electric quantity is transferred
from H5B plant to H6 plant, 3.21 million kWh electric quantity is saved. Eastern grid is sending grid. The start-up mode of N1 plant and T3 plant has larger influence than others. When 438 million kWh electric quantity is transferred from N1 plant to N2 plant, 16.82 million kWh electric quantity is saved. When 766 million kWh electric quantity is transferred from T3 plant to T1 plant, 16.96 million kWh electric quantity is saved in the middle grid.

4.3.3. The influence of electric quantity on network loss among the different areas. Unit power is adjusted and the change of loss quantity situation is analyzed among the different areas of aimed grid under the condition of power plant attribution. As shown in Table 2. Positive numbers mean electric quantity transfer in. Negative numbers mean electric quantity transfer out.

| Program | Power plant | Transfer quantity /MWh | Annual saving quantity /MWh | Attribution |
|---------|-------------|------------------------|---------------------------|-------------|
| 1       | H1B         | -74460.00              | 1462.67                   | H           |
| 2       | H5B         | 74460.00               |                           |             |
| 3       | H2B         | -70262.50              | 1018.72                   | H           |
| 4       | T3          | -56575.00              | 1990.72                   | T           |
| 5       | H6          | 70262.50               |                           |             |
| 6       | T1          | -74460.00              | 432.71                    | T           |
| 7       | H7          | 74460.00               |                           |             |
| 8       | H3          | -39420.00              | 356.58                    | H           |
| 9       | H5B         | 39420.00               |                           |             |
| 10      | H6          | -44712.50              | 563.22                    | H           |
| 11      | H1B         | -74460.00              | 1049.02                   | H           |
| 12      | T3          | 74460.00               |                           |             |
| 13      | T1          | -56575.00              | 232.03                    | H           |
| 14      | H7          | 56575.00               |                           |             |
| 15      | N1          | -52195.00              | 3247.41                   | N           |
| 16      | N4          | 52195.00               |                           |             |
| 17      | N1          | -41610.00              | 2461.66                   | N           |
| 18      | N3          | 41610.00               |                           |             |
| 19      | N1          | -43800.00              | 2485.55                   | N           |
| 20      | N6          | 43800.00               |                           |             |
| 21      | H1B         | -75555.00              |                           |             |
| 22      | H5B         | 38325.00               | 1007.63                   | H           |
| 23      | H4          | 37230.00               |                           |             |
| 24      | H2          | -72270.00              |                           |             |
| 25      | H6          | 43800.00               | 1194.08                   | H           |
| 26      | H4          | 28470.00               |                           |             |

According to the simulation results, we can see that when 745 million kWh electric quantity is transferred from H1B plant to H5B plant, 14.62 million kWh electric quantity is saved in the Group H between middle grid and eastern grid. When 566 million kWh electric quantity is transferred from T3 plant to H7 plant, 19.90 million kWh electric quantity is saved in the Group T. When 745 million kWh electric quantity is transferred from G1 plant to G2 plant, 19.61 million kWh electric quantity is saved in the Group G.

Between eastern grid and western grid, when 745 million kWh electric quantity is transferred from H1B plant to H4 plant, 10.49 million kWh electric quantity is saved in the Group H. When 522 million kWh electric quantity is transferred from N1 plant to N4 plant, 32.47 million kWh electric quantity is saved in the Group N.

5. Peroration
This paper studies aimed grid and obtains a result that on the basis of the economic benefit of each power generation group not being affected, optimizing unit power on the foundation of grid structure feature could reduce the network loss. The large capacity has greater influence than others and power plants in the sending power grid have greater influence than others in the power grid of local power balancing, so we can optimize unit power to achieve loss reduction on basis of installed capacity and load distribution, and constraint condition of power plant attribution. Compared with traditional loss reduction method, this method has the characteristics of high pertinence and low running cost. Because economic constrain condition is added, this method also can avoid conflicts of interests of each power generation group and has strong operability.

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