Analysis of line loss status and loss reduction measures in eastern Inner Mongolia Area

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Abstract. Loss reduction, energy saving, safe and stable operation of power grid are two major themes of power companies, among them, line loss is a comprehensive technical indicator for measuring and assessing the production technology and management level of power supply enterprises. It is also a comprehensive indicator for evaluating the operation level and production level of power enterprises. The loss is the inevitable cost of the power grid when transmitting power, which related to the planning, operation level and operational efficiency of the power grid, the calculation and analysis of the loss can effectively indicate the direction for the next step of the power grid and provide effective guidance for the economic operation of the power grid.

1. Introduction

Saving resources and green development is a long-term policy of China's social development. With the rapid development of the economy, the degree of electrification is getting higher and higher, the power load is increasing, the scale of the power grid is expanding, the structure is more complicated and diverse, and the power loss is also increasing year by year. How to effectively reduce the power loss has far-reaching significance for realizing the economic operation of the power grid. Doing this work well is not only related to the implementation of the national policy of energy conservation and loss reduction, but also improving the economic benefits of enterprises. Power supply companies actively pay attention to energy conservation and emission reduction work is also a way to practice social responsibility, and reducing line losses is one of the ways that power supply companies promote energy conservation, and is also the top priority of power supply companies. The line loss rate is an important economic indicator for assessing the management level of power supply enterprises. The line loss rate not only objectively reflects the level of power grid operation and management, but also relates to the economic benefits of the enterprise itself. Carrying out research on analysis and loss reduction measures has important theoretical significance and engineering value for the reliable operation of eastern Inner Mongolia power grid [1].

2. Line loss classification and composition

According to the line loss property, the line loss can be divided into four categories: statistical line loss, theoretical line loss, management line loss and economic line loss [2]. The statistical line loss is also called the actual line loss, calculated according to the reading of the electric energy meter, that the difference between the power supply quantity and the power sales quantity. The theoretical line loss is the loss of electrical energy of the power supply equipment in the transmission and distribution of
electrical energy. The loss is calculated theoretically according to the basic parameters and operating parameters of the power supply equipment. Management line loss refers to other losses or unknown losses, including the error of the metering device (electric energy meter, voltage transformer, current transformer and the error of the connection device between them). The economic loss is the power loss corresponding to the lowest theoretical line loss rate. Generally, the line condition is fixed, but the theoretical line loss is not fixed and will change with the change of the power supply load. There will always be an operation situation. The theoretical line loss rate is the smallest, at which time the lost power is an economic loss, and the corresponding current is called the economic current. The statistical line loss consists of two parts: the management line loss and the theoretical line loss. The theoretical line loss and the statistical line loss should be consistent or close. If the calculation is accurate and the difference between the two is large, the management line loss is too large, that is, the line loss, there is a need for improvement in management.

The loss of the power grid can be divided into two categories according to its characteristics, nature and law of change [3], constant loss and variable loss. The constant loss is also called the fixed loss. The magnitude of this loss is independent of the change of the load current. It is related to the voltage change, and the system voltage is relatively stable, so the loss is relatively constant. Such as transformers, motors, electric energy meters and other iron core power loss, as well as high-voltage line corona loss, insulator loss. Variable loss is also called unfixed loss. This kind of loss is generated when the resistance of each component of the grid passes through the current. The magnitude is proportional to the square of the current. The loss will change with the load. Such as power line losses, losses in the transformer windings. The line loss in the power grid generally consists of the above two types of losses.

3. The meaning of power line loss rate and the significance of carrying out theoretical calculation

The percentage of the line loss power to the power supply is called the line loss rate. The calculation formula is as follow:

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\text{Line loss rate} = \frac{\text{Line loss power supply}}{\text{Power supply}} \times 100\% \\
= \frac{(\text{Power supply} - \text{Electricity sales})}{\text{Power supply}} \\
= (1 - \frac{\text{Electricity sales}}{\text{Power supply}}) \times 100\%
\] (1)

Among them, the amount of power supply refers to the total input power of the production activities of the power supply enterprise. Power supply is equal to generating capacity minus power consumption and output, plus the sum of purchasing power and input power; electricity sales are the amount of electricity that power enterprises sell to customers (including wholesale power). The line loss rate is an important technical and economic indicator for the state-assessed power supply enterprises. The indicators cover a wide range. The generation, transmission, transformation, distribution and use of power grid are all related to line loss. Therefore, the line loss rate is also the comprehensive performance of the power supply enterprise management level. It can be used to measure whether the grid structure and layout of the power supply enterprise is reasonable, whether the operation is economical, and whether the measures taken are effective.

The theoretical calculation plays a guiding role in reducing loss and saving energy, and promoting the deepening and scientific management of line loss [4,5]. The calculated proportion of various line losses can provide reliable basis for line loss analysis, and then find out the weak links of the power grid and determine the main direction of loss reduction. The calculated theoretical line loss rate can be compared with the statistical line loss rate, so as to know the level of enterprise management and whether the actual line loss rate statistics are reasonable [6].

4. Research content and calculation method

At present, combined with the actual situation of the power grid, a large number of theoretical studies...
have been carried out both at home and abroad on the theoretical line loss calculation method of power grid, reaching a high level. Some calculation methods have been put into practical application and good settlement results have been achieved [7,8]. For power generation and power supply companies, reducing power consumption means saving energy and increasing economic efficiency [9-11]. In order to make the calculation results more accurate, the power flow calculation method is adopted in 35 kV and above power grids in eastern Mongolia. The injection power of 35 kV and above power grid nodes needs to input 24-point load data of 10 kV side of 35 kV substation. The power of each generator injected into the grid at each hour of the day, the input mode of reactor and capacitor is simulated in the program according to the actual operation mode, and the input and output power of the external power grid is input into the program according to the 24-point data. 35kV and above are calculated as a whole, each district power grid uses 220 kV substations and power plants connected with 110 kV and below in the area as power points and operates in different sections. Therefore, 220 kV buses of 220 kV substations exist as balancing nodes. The generator data is the injection power of 24 points to the power grid, and the load data is intercepted to the 10 kV bus of the substation as the load point and enters the 24 point load data. The generator data is the injection power of 24 points to the grid. For power grids with voltage grade of 10 kV or below, the calculation method of electric quantity is adopted, and the data of electric quantity on a representative day is taken as the priority for calculation. The 380 V station area selects the typical station area to carry out three-phase unbalance calculation.

The theoretical calculation of line loss in Eastern Inner Mongolia power grid includes the comprehensive line loss rate of the whole power grid on the representative day, layered line loss rate, component line loss rate, sub-area line loss rate, the capacity-load ratio of different voltage levels and so on. Main transformer loss, line loss, reactor loss, capacitor loss and station power consumption in 10 kV and above voltage level grids, low voltage line loss and instrument loss in typical 400 V low voltage station area, etc.

5. **Comparative analysis of simulation calculation results and statistical values**

In order to make the theoretical calculation of line loss representative, the theoretical line loss calculation is carried out on August 8 as a typical representative day. The maximum load on the representative day is 5446.6 mw, which is 86.06% of the annual maximum load predicted by the system. The power supply on the representative day is 93% of the power supply on the maximum load day, which means that the load level on the representative day basically represents the larger load level of the power grid. The theoretical calculation uses the professional theoretical line loss calculation software developed by Da Fang Company. The required data and equipment operation on the representative day are shown in tables 1 and 2.

| Area | Data |
|------|------|
| 35 kV And Above Power Plants And Substations | The whole point of active, reactive, active power, reactive power, voltage, current and accumulated power throughout the day, bus voltage, transformer tap position and capacitor, reactor operation data, all-day station power consumption and each outlet, mother Combined switch state table |
| 10 kV Trunk Line | Total Meter's Full Point Electricity and Full-day Accumulated Electricity |
| Distribution Transformer | Accumulated electricity throughout the day |

| Table 1. The required data of calculation. |
Table 2. Operation of equipment on representative day.

| Voltage level, subarea | Number of Running Lines | Number of Running Length (km) | Number of substations | Number of running transformers | Operating transformer rated capacity (MW) | Operating transformer maximum load (MW) | Capacity ratio |
|------------------------|-------------------------|-------------------------------|-----------------------|-------------------------------|------------------------------------------|----------------------------------------|---------------|
| 500kV                  | 34                      | 3549.07                       | 9                     | 16                            | 12900                                    | 2173.81                                | 5.93          |
| 220kV                  | 293                     | 11542.09                      | 77                    | 120                           | 16005                                    | 3730.53                                | 4.29          |
| 110kV                  | 108                     | 2936.33                       | 79                    | 102                           | 3448.6                                   | 539.83                                 | 6.39          |
| 110kV in Hulun Buir All Regions | 108 | 2936.33 | 79 | 102 | 3448.6 | 539.83 | 6.39 |
| Whole Network 66kV     | 687                     | 12298.42                      | 615                   | 10207.12                      | 2571.96                                  |                                        | 3.97          |
| 66kV in All Regions    | Chifeng                 | 316                           | 5364.12               | 228                           | 4575.30                                  | 1272.50                                | 3.60          |
|                       | Tong liao               | 241                           | 4209.03               | 163                           | 4440.85                                  | 994.88                                 | 4.46          |
|                       | Hing gan League         | 99                            | 1987.61               | 82                            | 1171.40                                  | 290.01                                 | 4.04          |
|                       | Hulun Buir              | 28                            | 669.7                | 20                            | 19.57                                    | 14.57                                  | 1.34          |
|                       | 35kV Hulun Buir         | 70                            | 1997.50               | 65                            | 361.15                                   | 62.21                                  | 5.81          |
|                       | 10kV                    | 2493                          | 93328.78/             | 133375                        | 16359.58                                 | /                                      | /             |

Based on the above-mentioned operation data, basic data and the operation status of power grid equipment on the representative day, the corresponding simulation model is established in the Da Fang line loss software, and the corresponding line loss rate of different voltage levels is obtained. The statistical value of the line loss rate and the theoretical value of different voltage levels of the whole power grid are shown in table 3.

Table 3. Comparison of statistical caliber and theoretical caliber of line loss rate for different voltage levels.

| Voltage level | 500kV | 220kV | 110kV | 66kV | 35kV | ≤10 kV |
|---------------|-------|-------|-------|------|------|--------|
| Theoretical line loss rate | 0.70  | 1.23  | 1.87  | 1.74 | 2.11 | 4.23   |
| Statistical line loss rate   | 0.73  | 1.36  | 2.05  | 2.35 | 2.21 | 6.88   |
| Difference Value             | 0.03  | -0.13 | -0.18 | -0.61| -0.10| -2.65  |

It can be seen from table 3 that the 500 kV power grid is relatively perfect, the grid statistical line loss rate and the theoretical line loss rate are basically the same, and the difference value between the statistical value and the theoretical value is 0.03, and the theoretical calculation of the line loss is close to the statistical value. The main reason why the theoretical value of 500 kV is lower than the statistical value is that the influence of corrugated line loss is not considered in the calculation of 500 kV. The 500 kV grid is mainly used for energy delivery, and the power flow varies little with local load. The theoretical calculation results of 500 kV line loss basically conforms to the actual operation level and management level of the voltage level power grid, and can reflect its loss situation to guide the development of the loss reduction work. The difference value between the statistical value and the theoretical value of 220 kV power grid is 0.13. The reason for the difference value is that the statistical caliber adopts the cumulative value from January to July. Because the power supply in eastern Inner Mongolia is the largest in July, the statistical value is larger than the theoretical calculation result. The 110 kV power grid exists only in the Hulun Buir area. The theoretical and statistical line loss...
difference value of the Hulun Buir area is 0.18, which indicates that our calculation data is true and reliable and can reflect the line loss management level in the area. The calculation results can guide the development of the loss reduction work. The theoretical and statistical line loss difference value of 66 kV and 35 kV are 0.61 and 0.1, and the deviation is large. The main reason is that the statistical line loss contains the peak of agricultural irrigation in July, which leads to the statistical value greater than the theoretical calculation result. The deviation also shows that there is room for loss reduction in this voltage level. It is suggested that the comparative analysis of this voltage level be carried out to find out the cause of high loss through detailed comparison of line loss and to solve the problem of high loss. The difference between theoretical and statistical line losses of 10 kV and below is 2.65. The main reason is that the data of 380 V stations are extracted by proportional method. The selected stations in different cities are not representative enough and the calculation results are deviated greatly.

6. Measures and suggestions for loss reduction

- Improving Grid Structure and Reducing Technical Line Loss
  We will further strengthen the structure of the 500 kV power grid in eastern Inner Mongolia, improve the load acceptance capacity of the region, and plan the new 220 kV substation in the regional area where seasonal loads (including agricultural irrigation and some industrial loads) are concentrated. The transmission and distribution lines of 110 kV power grid are comprehensively updated and reformed, and the overloaded lines are revamped as soon as possible. The partial load of the heavy-duty line is turned out to relieve the load pressure of the line. In time, high-loss lines should be included in the project of Engineering renovation, and the technical level and operation status of power grid should be improved by line cutting, and the large-section and insulated wire will be replaced so as to reduce losses and increase supply and reduce losses Reasonable planning of 380V low-voltage power network structure, reduce the power supply radius.

- Developing Economic Operation of Transformers to Reduce Technical Line Loss
  Because of the uneven and small load distribution in eastern Mongolia, there are a large number of light-load transformers and heavy-load transformers in some areas. It is recommended to speed up the construction of power grids in areas with heavy power flow, optimize the distribution of substations, improve the long-term heavy load of transformers caused by heavy load, optimize the network power flow, and avoid the circuitous power supply of power flow. Timely replacement of high energy consumption, old, heavy overload transformers, replacement capacity is more reasonable, technical level is higher, new energy-saving distribution transformers. For each light-load substation put into operation, reduce the occurrence of no-load operation, etc., plan the load-cutting scheme reasonably, and increase the load rate of the light-load transformer.

- Reasonable Configuration of Reactive Devices to Reduce Technical Line Loss
  It is recommended to increase reactive power compensation in substations with heavy loads, increase terminal substation voltage, increase power factor in low voltage station area, reduce long distance transmission of reactive power, and improve line loss.

- Balanced Area Load to Reduce Technical Line Loss
  Actively communicate with large regional users, timely follow-up project construction progress and load growth. For the slow development of Industrial Park load, should communicate with government departments, hoping that the government will increase investment and provide high-quality load for light-duty substation.

7. Conclusions
Line loss rate is an important economic and technical index of power supply enterprises, and it is also a concrete reflection of the production technology and management level of power supply enterprises. How to implement the national policy of laying equal stress on resource development and saving and putting saving first, how to strengthen basic management, optimize power grid structure, reduce power grid loss, strengthen line loss index management, power consumption management to achieve good
economic and social benefits is an important issue in line loss work. The theoretical calculation of line loss in power grid can further strengthen line loss management, clarify the composition of line loss and tap the potential of loss reduction, so as to achieve the purpose of scientific loss reduction. This paper calculates the theoretical line loss rate of the eastern Inner Mongolia power grid under different voltage levels based on the typical representative day data of the eastern Inner Mongolia power grid. After comparing with the statistical line loss rate, it is found that there are some technical and management problems in the eastern Inner Mongolia power grid, such as weak grid structure, light transformer load, long power supply radius, etc. According to the above problems, measures to reduce losses such as improving grid structure, developing economic operation of transformers and balancing regional loads are put forward.

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