Analysis and Evaluation of Power Grid Loss Reduction from the Perspective of Operation Inspection Based on Risk Theory

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Abstract. The use of electric energy has become an indispensable and important part in people's daily life and production, but there is a certain line loss rate in the process of electric energy transmission. Line loss is the power consumption of transmission lines and equipment in power grid, which is an important skillful index to measure the power loss level of power supply enterprises, and also reflects the power system design, operation, management and economic benefit level of enterprises. Line loss is an important skillful index to measure the power loss level of power supply enterprises, and it is also the embodiment of power system design, operation, management and economic benefit level of enterprises. At present, the scale and scope of power grid construction are constantly expanding, which makes the loss of power and energy increase, and affects the economic benefits of distribution network operation. Based on risk theory, this paper analyzes and evaluates the existence and composition of power loss in the process of power transmission and theft, and puts forward effective measures to reduce power loss in the operation and inspection, so as to more effectively improve the utilization rate of power and economic benefits.

Keywords: Electric power system; Line loss; Transportation inspection

1. Introduction

As one of the important pillars of the national economy, electric energy is related to the sustainable development of our society. In the power system, power is produced by power plants, and ultimately supplied to users through the transmission, transformation and distribution of power grid [1]. At this stage, the scale and scope of power grid construction continue to expand, making the power energy loss also increase, affecting the economic benefits of distribution network operation [2]. After the electric energy is produced by the power plant, it needs to go through a series of links to supply users. However, in the process of power transmission, transformation and distribution, due to the influence of various factors, it often has a certain loss [3]. The power loss of power network not only consumes certain power resources, but also occupies part of the capacity of power generation equipment [4]. We
all know that there is a basic law of energy conservation in the process of energy transfer. With the continuous development of social economy and the increasing demand of people's electricity consumption, the line loss of distribution network is gradually paid attention to by power supply enterprises, and the line loss of distribution network is predicted by equivalent resistance, power flow calculation, station loss rate and other methods [6]. From the point of view of the current market economy and national economy, the economic operation of the power system and the production, transmission and consumption of electric energy must pay attention to economic benefits. All power users should save electricity and reduce electricity consumption [7].

In the process of power transmission and distribution, it is inevitable to consume electric energy, because there are various transmission lines, transformer lines, transformers, compensation equipment and metering protection equipment in the power grid [8]. Power loss is a comprehensive problem covering many aspects, including management loss and technical loss. Power outages will inevitably occur during grid operation. Measures should be taken to reduce losses [9]. Line loss is the power consumption of power grid transmission lines and equipment. It is an important technical indicator to measure the power consumption level of power supply enterprises. It is also the embodiment of power system design, operation, management and enterprise implementation [10]. In order to effectively reduce the grid loss during the operation inspection, it is necessary to adjust the system voltage and the main transformer tap switch to ensure the safe and stable operation of the transformer, complete the renovation project of the old equipment, and strengthen the contact resistance of the electrical equipment and the management of the grid loss [11]. Therefore, it is necessary to adopt effective methods to estimate the theoretical line loss of the ship's prospects, and take reasonable and feasible measures to reduce the line loss. Based on risk theory, this paper analyzes and evaluates the existence and composition of power loss in the process of power transmission, transformation and stealing, and proposes methods to effectively reduce power loss during transportation and inspection, thereby improving power utilization rate and economy benefit.

2. Cause analysis of loss reduction in distribution network

In the transmission process, the thermal effect caused by the current working on the power equipment occupies a considerable loss. If the power supply voltage is constant, the power equipment such as transformers and transmission lines will have a voltage drop. In some areas, the construction of distribution network lags behind, while the power demand is in a trend of rapid increase, resulting in unreasonable power distribution, including unreasonable line layout and optimization. Transformer is the main electrical equipment in the process of power production. The total capacity of transformer running in power grid is several times or even ten times of the total capacity of generator and motor [12]. In the process of transformer operation, that is, transformation, the active and reactive power consumed by the transformer itself accounts for a large part of the loss, which is commonly referred to as transformer iron loss and copper loss. Power flow algorithm is not only difficult to collect data, but also may lead to non-convergence in calculation. It is generally used in planning and design or line loss analysis, but rarely used in actual line loss calculation. The line loss problem is mainly caused by the long running line of distribution network, and the relatively large no-load loss and copper loss of transformer, which makes the load fluctuate greatly, resulting in low utilization rate of distribution line and transformer equipment, increased voltage fluctuation and large network loss.

Define a set of r targets \( O = \{O_1, O_2, \ldots, O_r\} \), and a domain \( A = \{a_1, a_2, \ldots, a_n\} \) of n schemes. Let \( O_i \) denote the i-th goal, the membership degree of scheme a in \( O_i \) is recorded as \( \mu_{O_i}(a) \), so the decision function D should be the set of all goals:

\[
D = O_1 \cap O_2 \cap \ldots \cap O_r
\]

(1)

Therefore, the membership degree of decision function D for each scheme is:

\[
\mu_a(\alpha) = \max[\mu_{O_1}(\alpha), \mu_{O_2}(\alpha), \ldots, \mu_{O_r}(\alpha)]
\]

(2)

The most ideal decision scheme \( a^* \) will satisfy the following scheme:
\[ \mu_D(\alpha^*) = \min \{\mu_D(\alpha) \forall a \in A\} \] (3)

\( a^* \) represents the optimal solution, and \( A \) represents the set of components that may fail.

According to the actual load, it is determined when a single transformer is running and when in parallel operation, so that the transformer can be effectively controlled. Its own comprehensive loss. The current passing through the transformer chamber will create an alternating magnetic field. At this time, the transformer will step up or step down according to the operation of the current. A rotating magnetic field will be established during the process of passing through the motor. Its main function is to promote the operation of the motor. The work. Taking construction measures can increase the transmission capacity of the distribution network and improve the voltage capacity. The operation measures do not require investment or less investment, and only select the most economical and reasonable operation mode for the distribution network to achieve the goal of reducing line losses.

The transformer under the unbalanced operation of the three-phase load will produce zero sequence current, and the existence of the zero sequence current inside the transformer will produce zero sequence magnetic flux in the iron core. These zero-sequence magnetic fluxes will form a loop in the tank wall of the transformer or other metal components. The power loss classification of the power grid is shown in Figure 1.

![Fig.1 Classification of grid power loss](image)

In the current construction process of transmission and distribution lines, technicians generally use copper or aluminum materials as connecting wires of transformers and motors, and when the current passes through these wires, there will be a certain resistance, which is the resistance of conductors. Usually, in the process of line loss prediction, analysis and calculation in low-voltage distribution network, the electrical parameters of ground charging capacitor and ground admittance of transformer can be ignored. In this way, the number of radiation branches in the whole low-voltage distribution network will exceed the number of closed circuits, so the line loss can be calculated by the loop current equation [13]. In the process of power transmission, the electrical energy will overcome the resistance of the conductor in a certain form, and eventually produce a certain amount of electrical energy loss, at which time the conductor and equipment will heat up. The rationality of distribution network design layout and structure has a direct impact on power supply line loss. Therefore, it is necessary to optimize the design and rationally adjust the power grid structure on the premise of ensuring the power supply quality of the distribution network.

3. Loss reduction strategy of distribution network in operation and inspection

In order to reduce the line loss of distribution network, it is the most direct way to reduce the transmission circuit. In the process of current transmission, if the power supply voltage remains unchanged, the power equipment will have a voltage drop. Decentralized compensation, that is, on-site compensation for electrical equipment, aims to reduce reactive power absorbed or sent back to the power grid by the electrical equipment at the end of the line, which can also reduce current and loss. The difference between actual line loss and technical line loss can be used as one of the indexes to measure the management level of power supply department. The technical line loss can be reduced to a very low level technically. However, combined with the economic benefits of the power grid, it should only be reduced to a reasonable level. What is reasonable in the end depends on the social conditions and power grid structure at that time. For the early construction of distribution network, the distance
between power supply and load center should be narrowed to the maximum extent to reduce the line loss. When configuring power points, the environment, operation requirements and economic power supply radius of distribution network should be fully considered [14]. If the main transformer of substation adopts the on-load voltage regulation method to adjust the voltage, which can realize the voltage adjustment without power failure, the voltage range can be adjusted according to the actual situation of real-time load, so as to avoid the power system voltage quality degradation due to the peak power consumption, and improve the terminal voltage of power supply line, thereby reducing the line current and reducing the loss of distribution network. Transformer consumes a certain amount of reactive power during operation, and the line loss caused by reactive power loss is sometimes very serious. Therefore, in order to reduce the line loss in the distribution network of power supply enterprises, the loss reduction of distribution network transformers must be considered.

Each power supply station shall establish an effective management mode and incentive mechanism, with detailed index assessment, responsibility to people, work efficiency linked assessment and quantification, and strengthen the line loss index assessment. Common sense shows that the resistance and reactance of a conductor are inversely proportional to its cross-sectional area, so the resistance and reactance of a line with a small cross-sectional area are large, and the loss of active power and reactive power will be greater when the same capacity load is transmitted. When erecting the power supply distribution network, it should be connected to the surrounding area in a relatively independent form according to the configuration of each power point. The operation and inspection link is the front line of loss reduction in distribution network, which requires the operation and inspection personnel to take effective corrective measures according to the operation and inspection plan in order to achieve the goal of loss reduction [15]. The personnel in the station area need to focus on strengthening the abnormal rectification work of metering devices to ensure the rectification efficiency, avoid the problem of missing rectification and avoid the difficulty of collecting data in the station area. In the transmission and distribution network, the contacts of various electrical equipment, including the connections of transmission lines, circuit breakers and disconnectors, current mutual inductance and other leads, all have contact resistances with corresponding standard values. Figure 2 shows the scanning speed modulation architecture of the power prediction model.

The objective function can be expressed as:

\[
C(P_G) = \sum_{i=1}^{n} C_i(P_{G,i})
\]

At the same time, the following power balance conditions are met:
\[ P_a - \sum_{i=1}^{n} P_{G,i} = 0 \]  

\( P_G = [P_{G,1}, P_{G,2}, \ldots, P_{G,n}] \) is the output vector composed of the output of each generator, \( P_{G,i} \) is the active output of the i-th generator, and \( C_i(P_{G,i}) \) is the cost function of the i-th generator, which is the total load of the power grid.

In order to effectively reduce power supply line loss, power suppliers should strengthen power grid loss management, clarify the responsibilities of each department, and implement line loss management. In order to effectively improve the efficiency of ship prospect loss reduction management, we adopt hierarchical management of line loss rate indicators, release line loss rate plan indicators in a timely manner, and assign line loss rate indicators to specific personnel. With the continuous development of social economy, power supply companies are developing rapidly, and the network structure of ship prospects is also developing rapidly. However, the network structure during the line-of-sight operation is directly related to the line-of-sight loss. The original network structure has caused a lot of line loss and caused serious economic losses to the power supply company. Therefore, the network structure of distribution network should be optimized, so as to achieve the purpose of loss reduction in distribution network of power supply enterprises.

If the main transformer of substation adopts the on-load voltage regulation method to adjust the voltage, it has the condition of adjusting the voltage without interruption. According to the real-time load situation, adjust the on-load voltage regulation switch of transformer to ensure that the system voltage meets the floating range specified in the regulations, so as to avoid the system voltage quality degradation caused by the peak load. At the same time, it also effectively improves the voltage at the end of the power supply line, and reduces the line current, thus achieving the purpose of reducing the power loss. Figure 3 shows the framework of fault diagnosis system.

![Fault diagnosis system framework](image)

**Fig.3** Fault diagnosis system framework

The line loss changes with the change of current and resistance, because it has a square relationship with current, so the change of current has a great influence on the line loss, and the current on the wire is reasonable, which should not only meet the safety requirements, but also have the provisions of economic current [16]. The load characteristic of transformer loss rate is a nonlinear function. Through complex calculation and dispatching operation experience, the economic operation area of transformer
is found, and when a single transformer runs and when it runs in parallel is decided according to the actual load, so that the comprehensive loss of transformer can be effectively controlled. Adjusting the operating voltage properly within the allowable range can not only improve the power quality, but also reduce the line loss and achieve the purpose of economic operation. Generally, the operation voltage can be adjusted by adjusting transformer taps and switching capacitors. Common sense shows that the resistance and reactance of a conductor are inversely proportional to its cross-sectional area, so the resistance and reactance of a line with a small cross-sectional area are large, and the loss of active power and reactive power will be greater when the same capacity load is transmitted [17]. For several transformers running in parallel in substation, the economic operation should be considered, and the economic operation mode should be determined by the transformer loss. The substation operation and maintenance work adopts infrared temperature measurement or flaw detection, and the found ultra-high temperature at the equipment link joint is the concrete manifestation of power loss.

4. Conclusions

From the point of view of operation and inspection, the effective development of power grid loss reduction needs to do a good job in line operation and maintenance management, timely rectify faulty equipment, and focus on transformer management. In actual prediction, the correct calculation method must be selected to ensure the accuracy of theoretical line loss calculation results. When configuring power points, the environment, operation requirements and economic power supply radius of distribution network should be fully considered. The technical transformation of power loss reduction in power grid is a systematic project, which not only pays attention to the specific loss reduction measures in each link from the micro level, but also strengthens the management from the macro level. The operation and inspection link is the front line of loss reduction in distribution network, which requires the operation and inspection personnel to take effective corrective measures according to the operation and inspection plan in order to achieve the goal of loss reduction. According to the deviation between actual line loss and theoretical line loss, power supply enterprises can analyze the reasons of line loss difference concretely, and take targeted measures to reduce loss, such as optimizing distribution network structure, reducing technical loss and strengthening line loss management. Thereby effectively improving the efficiency of distribution network operation, ensuring the economic benefits of power supply enterprises, and comprehensively promoting the good development of power supply enterprises.

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