Research on Visual Monitoring System of Line Loss in Power Internet of Things and Power Distribution Network

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Abstract. In order to reduce the comprehensive line loss of the power grid, a visual monitoring technology of line loss in the distribution network based on the Internet of Things is proposed. The paper incorporates the monitoring and management of line loss during the same period into the visualization platform of the distribution network to monitor and manage the effectiveness of the whole process, and solve the problems of incomplete information, untimely filing, and inadequate updates, and fully support "one data source, one grid map, and one business line" The construction and application of the ubiquitous power Internet of Things. Based on the Internet of Things technology, the article screens the distribution network line loss data for the same period and uses Tableau software to make a visual worksheet, visualizes the line loss data, analyses the relationship between the distribution network line loss data for the same period, and conducts anti-theft analysis on the same period distribution network. The paper then performs K-means algorithm clustering analysis, visual analysis and box plot analysis on the line loss data. Summarize the threshold range of each line loss index corresponding to different conditions such as abnormal station area, to-be-upgraded station area and normal station area. Finally, build a visual interactive platform for the analysis of line loss abnormalities in the station area. Experiments have proved that the line loss visual monitoring system can control the overall situation of line loss and the processing of abnormal line loss in real time, which greatly improves work efficiency.

Keywords: Power internet of things, line loss management at the same time, visual management system, power grid planning.

1. Introduction

Traditional line loss index management is mainly based on manual statistics. Affected by the statistical cycle, the line loss rate fluctuates seriously, the degree of integration between disciplines is not high, the integration of business data is not high, the accuracy and authenticity of basic data are difficult to verify, and it is cross-professional. The business process and work interface are not clear, the line loss exception processing cycle is long, and the process is lack of lean control. At present, the line loss system of the State Grid has four models of line loss in the same period [1]. There are daily and monthly calculations, which improve the management level of line loss to a certain extent. However, there are also not refined
enough, such as line loss ranking statistics, high loss, heavy damage statistics, in addition, there are also insufficient intelligence, cannot be combined with the vivid display of the map, etc., and the handheld terminal is not supported, which is not effective in troubleshooting and feedback. The construction of a visualized intelligent management platform for the distribution network will solve these problems and make the management and governance of line losses in the same period more accurate, vivid and intelligent.

2. Description of the related theory of line loss during the same period

Line loss management is an important task for power companies. In all power grid systems, the line loss of the low-voltage distribution network accounts for about 40% of the total power network loss. Line loss management can have a huge impact on the economic benefits of power companies, which also reflects the study of power grid loss reduction the inevitability [2]. The statistical line loss refers to the difference between the total power supply measured by the electric energy meter and the total power sold. Power supply refers to the amount of electricity provided by power plants or power grids to users, including electricity lost in transmission and distribution. The electricity sold refers to the electricity sold by power companies to users, which can be expressed by formula (1):

\[ \Delta A = A_g - A_s \]  

In the formula: \( A_g \) is the amount of power supply; \( A_s \) is the amount of electricity sold; \( \Delta A \) is the statistical line loss. There are many factors that cause line loss in the station area. In actual work, it is mainly divided into the following categories. (1) Losses caused by power distribution equipment. There are a variety of electrical equipment on the power distribution line, such as transformer equipment, reactive power compensation equipment, assessment and measurement equipment, user measurement equipment, etc. Each device has a certain amount of energy consumption. (2) Losses caused by power distribution technology and network structure factors. Different power supply modes and different power supply radius will also affect the line loss. The farther the user's power supply radius, the longer the distribution line, and the more line losses caused. (3) The unreasonable structure of the power supply and distribution grid causes greater line loss. (4) The configuration of the transformer is also an important factor affecting the line loss. (5) The management method of power marketing will also affect the line loss. (6) At the voltage level in the lower power grid system, the line loss is calculated by calculating the difference between the electricity sales and the power supply for the low-voltage station area. However, due to the error of the electricity metering instrument or the different meter reading time and other factors, the electricity statistics are inaccurate, which affects the line loss. Loss the accuracy of the calculation.

3. Design of a visual system for line loss management based on the Internet of Things

Through the implementation of the line loss monitoring module at the same time, the visual management of line loss management at the same time can be realized, and the relevant professional and specific grid equipment of the city and county company can be fully grasped and accurately located. The line loss abnormality management shortcomings and the management progress of the same time are realized by APP. Single circulation, intelligent assistance to analyse the specific causes of high and negative losses, and provide technical assistance for related specialists. Make the management of line loss more intelligent, precise and efficient.

3.1. Architecture design

The paper uses Siji Vision to support the front-end comprehensive visualization construction, relying on Siji Maps, supports the same-screen display of different targets based on two and three-dimensional geographic spaces, covering urban buildings, infrastructure, power grids and other data, and supports 3D visualization, digital monitoring, and industry The thematic map and other applications are quickly constructed to meet the needs of "a map of the power grid" and the visualization of the distribution
network business; the use of Siji Vision to support the front-end comprehensive visualization construction, relying on the Siji map, supports the same-screen display of different targets based on the two-dimensional and three-dimensional geographic space [3]. Covers data such as urban buildings, infrastructure, power grids, etc., supports rapid construction of applications such as 3D visualization, digital monitoring, and industry thematic maps, and meets the needs of "a map of the power grid" and the visualization of distribution network services. The data layer is divided into map display, application, component service and data layer. The system displays data to the system application layer through the service layer line loss rate component, compliance rate component, and summary service component of each component, and monitors and analyses the line loss through the synchronous line loss monitoring module and handheld terminal APP, and then displays the line loss panoramic display by map display, Line loss equipment positioning, network-wide abnormal distribution and line loss abnormal work order management and control (shown in Figure 1).

![Figure 1. Synchronous line loss visual monitoring system structure](image)

### 3.2. Business Architecture

The synchronization line loss monitoring module calculates and synchronizes the calculation results of various indicators in the same period line loss system of the State Grid on a daily basis, and realizes the division, voltage division, bus levelling, main transformer, transmission line, and 10 kV sub-line in the panoramic map mode. Monitoring the daily and monthly compliance status of the power supply and sales and line loss in the sub-station area and the line loss model abnormality monitoring (shown in Figure 2).

![Figure 2. The business architecture of the line loss monitoring module during the same period](image)
3.3. Integrated architecture
The system mainly analyzes the calculation results and trend of the "four points" line loss, supplemented by the historical frozen data in the provincial big data, the use and acquisition intermediate library, and the marketing basic data platform, and the "four points" line loss abnormal equipment from the archives, Configuration, topology, acquisition and other aspects of in-depth analysis, to achieve the purpose of active data, abnormal evidence (shown in Figure 3).

![Database Diagram](image)

**Figure 3.** Database

4. Synchronous line loss management data processing algorithm
When the initial data source is obtained, relevant data mining and analysis cannot be directly carried out. This is because big data itself has a lot of "noise" and "dirty data". If you ignore such problems and directly conduct mining and analyse the initial data source, the mining results may be unsatisfactory, or even impossible to mine. In the face of huge initial data, the first thing to do is data reprocessing, and then it can be better analysed and researched. First, analyse and understand the problems that need to be solved, clarify the effective information fields of the data, and on this basis, use data reprocessing technology to process data source information and remove redundant "noise data" to support subsequent data modelling and improve the quality of data mining, which is conducive to mining and analysing the value of related data sources. Data reprocessing can be achieved in a variety of ways, such as: data cleaning, data integration, data conversion, data specification, etc. Data cleaning is generally to process the missing values in the original data, identify or delete outliers, smooth "noisy data", and deal with issues such as inconsistencies in the nature of the data. In order to achieve the requirements of data unification, formatting, and standardization, and to eliminate duplicate data in the original data [4]. Data integration is the combination of multiple data in the original data source into one data, for example, aggregating daily line loss data into monthly line loss data. Data conversion refers to the conversion of data into a form suitable for data mining through smooth aggregation, data generalization, and standardization. For example, the monthly electricity supply and sales data is transformed into two parts of time information and electricity supply and sales information. Data specification is to use principal component analysis to process data, and select a small number of data features from a large number of data features to simplify the data. The data obtained through data reduction technology is much smaller than the original data, but it almost maintains the integrity of the original data, greatly reduces the amount of data to be mined, and helps shorten the time required for data mining and analysis. The data reprocessing stage of this article requires the following steps.
4.1. Calculate the power supply radius of the station area

According to the longitude and latitude data of the electricity meter, the relevant coordinate information is extracted, and the power supply distance of the electricity meter of the user under the jurisdiction of each station area is calculated. \((x_0, y_0)\) is the latitude and longitude coordinates of a transformer in a low-voltage station area, and \((x_i, y_i)\) is the longitude and latitude coordinates of a user's electricity meter under the low-voltage station area. Set the power supply distance from the station area to the user as \( dist_i \), unit: meter.

\[
dist_i = 2 \times \arg \sin \left\{ \sqrt{\left( \frac{a}{2} \right)^2 + \cos \left( y_0 \times \frac{\pi}{180} \right) \times \sin \left( \frac{b}{2} \right)^2} \right\} \times r
\]

Among them,

\[
a = (y_0 - y_i) \times \pi / 180
\]

\[
b = (x_0 - x_i) \times \pi / 180
\]

\( r \) is the radius of the earth, equal to 6,278,137 meters. Here, we define that the power supply radius of a certain station area is equal to the power supply radius of the station area. The average value of the power supply distance of households, so the power supply radius \( dist \) of the station area:

\[
dist = \frac{1}{n} \sum_{i=1}^{n} dist_i (n \geq 1)
\]

4.2. Calculate statistical line loss and line loss rate

The monthly statistical line loss and line loss rate are calculated based on the power supply and sales information in the station area. The calculation formula is as follows:

\[
\Delta A = \frac{A_0 - A_1}{A_0} \times 100\%
\]

4.3. Data conversion

Because when using Tableau software to visually analyse the electricity supply and sales data, there is a lack of time dimension, so it is necessary to convert the monthly electricity supply and sales data into time and electricity supply and sales data. In addition, when performing K-means cluster analysis, detailed monthly power supply and sales data is required, and all line loss data needs to be deployed in a unified format.

4.4. Data filtering

The thesis uses the function calculation of Excel and the function of creating fields in Tableau to calculate the power supply radius corresponding to the station area. It is found that the calculated power supply radius has a part greater than 500 meters. This article studies the line loss management of low-voltage station areas. Generally speaking, the power supply radius of low-voltage distribution networks should not be greater than 300 meters in urban areas, and should not be greater than 500 meters in suburban areas. Therefore, the low-voltage station area is screened by the power supply radius, and the line loss data of the low-voltage station area is filtered with 500 meters as the upper limit. The larger the power supply radius, the higher the line loss rate. If there is a low-voltage station with a power supply...
radius of more than 500 meters, the line loss rate is too high. This station belongs to the station with abnormal line loss. Record the station number (TG-ID) to correlate the relevant station.

4.5. Data cleaning

4.5.1. Missing values. The data involved in this study includes information such as power supply and sales, line loss rate, statistical line loss, power supply radius, and number of households in the station area. For the processing of missing values, generally choose to fill in or delete the missing part. As shown in Table 1. Since the collection time is only 9 months relatively short and the amount of data is huge, with the help of the filtering function of Tableau software, the stations with missing values in the monthly line loss rate are deleted to ensure that the monthly line loss rate data of the station is Coherence and effectiveness. At the same time, delete the stations that do not correspond to the power supply radius, the number of households in the station area, and the electricity supply and sale information.

| Outlier type | Calculated field | TG-ID (different) | Processing method |
|--------------|------------------|-------------------|------------------|
| Monthly power supply is 0 | IF [power supply] =0, THEN[TG-ID], END | 3232 | delete |
| Monthly electricity sales are 0 | IF [Power Sales] =0, THEN[TG-ID], END | 2238 | delete |
| When the electricity sold is greater than the electricity supply | IF [Power Supply] < [Power Sales], THEN[TG-ID], END | 27785 | delete |
| When the line loss rate is greater than 20% | IF [Line loss rate] >20%, THEN[TG-ID], END | 13789 | Delete after record |

4.5.2. Outliers. We will delete abnormal data such as electricity sales greater than electricity supply, electricity supply but no electricity sales, electricity sales but no electricity supply in the station area, and special cases where the electricity supply and sales are all zero. At the same time, record the station area with a line loss rate higher than 20% and delete it. This part of the station area belongs to the obviously abnormal station area and needs to be dealt with first by the management personnel, and check whether the station area user has electricity theft, and find the station area line loss If the reason is too high, reduce the loss.

5. Data analysis and testing

5.1. Visual analysis of low-pressure station area

5.1.1. The relationship between the number of households in the station area and the line loss rate. The number of users belonging to different stations may be different. To study the relationship between the number of households in the station area and the line loss rate, first make a ring diagram of the distribution of the number of households in the station area [5]. Figure 4 is a statistical chart of the distribution of the number of households in Taiwan. According to less than 100 households, 100 to 200 households, 200 to 500 households, 500 to 1,000 households, and more than 1,000 households, the number of households in Taiwan is divided into five categories.
Figure 4. Distribution of households in Tai District

The number of households in the station area is a discrete value. Consider grouping the number of households in the station area. According to the number of households in the station area after grouping, calculate the average line loss rate. The results are shown in Table 2 below.

Table 2. Number of households in Taiwan area and line loss rate

| Household Classification | Line loss rate |
|--------------------------|---------------|
| [Number of Households in Taiwan District] X100 | 5.77% |
| 100= [number of households in station area]X200 | 6.81% |
| 200= [number of households in station area]X500 | 6.85% |
| 500[number of households in station area]X1000 | 6.32% |
| 1000[number of households in station area] | 8.30% |

It can be seen from Table 2 that, as the number of households in the station area increases, the line loss rate also increases. However, when the number of households in the station area is less than 1000 and greater than or equal to 500, the line loss rate in this interval is reduced. It is considered that it may be affected by the abnormal value of the number of households in the station area. Then make a scatter plot of the number of households in the station area and the line loss rate, as shown in Figure 5 and Figure 6. Figures 5 and 6 distinguish different prefecture-level power supply companies through different colours. The time and prefecture-level filters of the former are selected. All data are selected to show the households in the districts of 11 prefecture-level power supply companies within 9 months. The relationship between the number and the line loss rate; the latter's time and city filter, select the specific time and the number of households and line loss rate of the city-level power supply company (A power supply company in September 2017) The relationship between.
In general, as the number of households in the station area increases, the line loss rate will also increase. However, as the number of households in the station area increased, the line loss rate of Power Supply Company A in Figure 6 had a tendency to decrease in September 2019.

5.1.2. Statistics on the relationship between line loss and line loss rate. When researching and analysing the line loss problem, whether it is the line loss rate or the statistical line loss, it is necessary to involve the specific number of households in the station area. The line loss rate in some stations is not high, but the statistical line loss is very large, which is caused by the large number of households in the station. In the same way, there is a high rate of line loss, but the statistical line loss is not large, which is caused by the small number of households in the station. Therefore, it is unreasonable to find the relationship between the two regardless of the number of households in the district. Figure 7 shows a scatter plot of statistical line loss and line loss rate based on the average line loss rate on the horizontal axis and the sum of the statistical line loss as the vertical axis. Different colours and shapes distinguish groups of
different numbers of households. Then further research and analysis of the scatter plots under each group. Figure 8 is a scatter plot of the statistical line loss and line loss rate under the number of households in different stations. Add trend line analysis to further research and analyse the scatter diagrams under each group [6]. It can be concluded that when the statistical line loss is consistent, the larger the number of households in the station area, the smaller the line loss rate, and there is a linear correlation between the two. The greater the absolute value of the linear correlation coefficient, the stronger the correlation. It can be seen from the figure that with the increase in the number of households in the station area, the correlation between the statistical line loss and the line loss rate has strengthened. The number of households in the Taiwan area is between 500 and 1000, and the correlation is strongest, which may be caused by the abnormal number of households in the Taiwan area.

**Figure 7.** Statistical line loss and line loss rate scatter plot

**Figure 8.** Scatter plot of statistical line loss and line loss rate for the number of households in the station area <100

5.2. Analysis of Anti-Stealing Electricity in Low-Voltage Station Area

Use time as the dimension and line loss rate and statistical line loss as the measurement to make visual charts. In order to quickly compare the information value of each data and find the trend of the data, the
bar graph and the line graph alone cannot fully meet the needs. At this time, a composite graph of the two can be constructed to show the line loss rate and statistical line loss information. As shown in Figure 9, a composite graph made with time as the horizontal axis and line loss rate and statistical line loss as the vertical axis (dual axis) can be used to distinguish power supply companies at different prefecture levels by the colour of the broken line and the bar. The area occupied by the bar graph also reflects the size of the statistical line loss. By selecting filters related to prefectures and cities, the line loss rate and statistical line loss changes of power supply companies at different prefecture and city levels can be reflected [7]. It can be seen from Figure 9 that G Power Supply Company’s statistical line loss sum total is the largest, but the line loss rate changes relatively smoothly. K Power Supply Company has the smallest sum of line loss statistics, but the line loss rate fluctuates in a large range. By selecting the filter of a specific station area, it can reflect the composite graph of the line loss rate and statistical line loss of the specific station area, showing the change trend of the line loss rate of the specific station area and the comparison of the level of statistical line loss in different time periods. Through the filter, it is helpful for the staff to understand the general situation and change trend of the line loss in the abnormal station area when investigating the abnormal station area. And provide reference for subsequent analysis. The line loss rate of the station area 1461 was relatively high in November 2019 and May 2020, and it needs to be analysed to determine whether the high line loss rate of the station area is caused by users' electricity theft.

![Figure 9. Composite graph of line loss rate and statistical line loss](image)

6. Conclusion

After the distribution network visualized intelligent management and control platform (synchronous line loss monitoring) system is launched, it will promote the digital and intelligent transformation of the distribution network, and comprehensively improve the perception and interaction level of the distribution network, as well as the safety, stability and economy of the distribution network operation. Effectively guarantee the power supply reliability of the power system and reduce the line loss rate. It helps to comprehensively improve the quality of customer service level, quickly respond to customers' electricity demand, reduce average power connection time, proactively notify power outages, reduce the number of power outages in the distribution network, shorten the time for emergency repairs, create a good business environment, and improve customers Satisfaction with electricity consumption.

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