Research on Statistical Method of Distribution Network Reliability Based on Dispatching Operation Management

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Abstract. Distribution network reliability statistics have always been an important indicator of the effectiveness of distribution network construction. In view of the characteristics of traditional manual statistics, such as heavy workload, low efficiency and poor accuracy, this paper starts from the demand of reliability analysis and combines with dispatching management system to realize automatic collection and recording of operation data related to reliability. Finally, according to the actual situation of the project site, a variety of distribution network reliability statistical methods are proposed.

1. Introduction
At present, most of the basic work of reliability statistics is in the charge of special personnel. Through reading the operation duty records, dispatching logs, planned outage application, load records and accident report data, and then combining with the relevant graphic information, the collection of basic operation data of reliability statistics is completed manually, and the workload is very huge. Therefore, we hope to adopt a distribution network reliability statistics method based on dispatching job management, which combines the collection of reliability statistics data with the daily work of dispatching, records the relevant information automatically in the daily dispatching work, and at the same time try not to add too much workload to the dispatcher [1].

2. Reliability statistical requirements
At present, the data sources of reliability statistics include two aspects, one is the operation data of distribution automation system, the other is the record file of the actual operation of distribution equipment. Among them, the most critical is the relevant data of operation record. According to the reliability demand of distribution automation in China, we divide it into three parts.

(1) The first stage: combine with the scheduling job management system to achieve reliability data collection, mainly focusing on the automatic recording of equipment operation reliability data.

(2) The second stage: online calculation and statistical analysis of reliability index, which mainly depends on distribution automation system.

(3) The third stage: the prediction and analysis of reliability, such as the guidance of planned maintenance, etc. the premise of this stage is the accurate entry of reliability statistical data of distribution automation system.

The emphasis of this implementation method is how to combine with the scheduling job management system to realize automatic / semi-automatic collection and recording of operation data related to reliability. The other two parts are not discussed in this method [2].
3. Statistical analysis

3.1. Reliability statistics
Reliability statistics methods include user-based methods, distribution transformer-based methods, and power or electricity-based methods. User-based is the most commonly used method, simple and easy, reliable data, no need to classify various users; statistical methods based on medium-voltage distribution transformers are more suitable for areas with imperfect metering equipment, automation devices and communication devices. Countries and regions where user distribution and power consumption information are not very accurate; statistics based on power or electricity use power (or electrical energy) as the weight, and statistics on user reliability or power outage time. The three have their own pros and cons, and major countries in the world adopt different methods for different considerations.

Table 1. Status of reliability statistics in various countries

| Statistical methods                        | Country or region                              |
|-------------------------------------------|-----------------------------------------------|
| Based on user                             | French power distribution network, the United  |
|                                           | Kingdom, Italy, Australia, the United States,  |
|                                           | Singapore and Hong Kong                        |
| Based on distribution transformer         | Norway, Poland and China                      |
| Based on power or electricity             | Spain, France medium-voltage power grid        |

3.2. Consideration of planned outages
When calculating power outage indicators, whether planned power outages should be ruled out or not depends on different countries’ perspectives, and there are also certain differences in actual practices. U.S. power supply reliability data is mainly collected and compiled by power supply companies. Power supply reliability regulatory agencies that exercise supervision rights on behalf of power consumers are less concerned about and intervening in the operation of power supply enterprises, and do not care whether the interruption of power supply is caused by planned or unplanned reasons. Therefore, most of the reliability data of the United States, Canada and other countries include planned power outages.

Unlike the United States, the United Kingdom and other countries are responsible for the management of power supply reliability by national power regulatory agencies, which care about both the power supply service level and the reliability and performance of the power grid. The United Kingdom believes that the reliability of the power grid has little to do with planned power outages. Therefore, when evaluating the power grid, planned power outages are often excluded and only unplanned power outages are considered. The situation in France, Italy, Sweden, Singapore and Japan is similar to that of the United Kingdom.

Table 2. Differences among countries’ planned power outages included in power outage indicators

| Outage indicator                          | Country                                      |
|-------------------------------------------|----------------------------------------------|
| Taking into account planned power outages | United States, Canada, China                 |
| Does not take into account planned power outages | United Kingdom, France, Italy, Sweden, Singapore, Japan |

4. Reliability statistical index
In general, 110kV and below voltage level of power system are called distribution network, 35kV and above are called high voltage part, 10kV and 6kV (including 20kV) are called medium voltage part, and 0.4kV part is called low voltage part. At present, most domestic distribution network reliability
refers to medium voltage part. Therefore, this paper is only limited to the introduction of medium voltage power supply reliability.

The reliability of power supply system includes the reliability of power supply system and the reliability of power supply system. User power supply reliability is considered from the perspective of users, that is, the ability of power supply system to continuously supply power to users; system reliability is considered from the perspective of power supply department, that is, the ability of power department to ensure user power supply reliability and maintain the best condition of power system. Distribution system reliability can be divided into two aspects: measuring past performance and predicting future behavior. Measure the past performance: carry out historical reliability statistics, analysis and evaluation on the existing operating distribution system, which is an extremely important part of the reliability evaluation of the whole distribution system and the basis of reliability prediction and evaluation; predict the future behavior refers to the reliability prediction and evaluation of the power supply capacity of the existing system, which can evaluate and predict the impact of various equipment on the system. They are closely related, and they are two indispensable aspects of distribution system reliability statistics [3-4].

Several main indexes of reliability statistics are calculated as follows:

4.1. Average outage time of users
The average outage time of users refers to the average outage hours of power supply users in the statistical period. The calculation formula of average outage time of users is as follows:

\[
\frac{\sum (\text{power outage time per household})}{\text{total number of users}}
\]  

or

\[
\frac{\sum (\text{duration of each outage} \times \text{number of users per outage})}{\text{total number of users}}
\]

The calculation formula of average outage time (excluding external influence) is as follows:

\[
\text{Average outage time of users} - \text{average outage time of users affected by external factors}
\]

The average outage time of users affected by external factors is calculated as follows:

\[
\frac{\sum (\text{duration of each external impact outage} \times \text{number of households affected by each outage})}{\text{total number of users}}
\]

The calculation formula of the average outage time of users (excluding the power limitation due to insufficient power supply of the system) is as follows:

\[
\text{Average outage time of users} - \text{average power cut time of users}
\]

The calculation formula of the average power cut time is as follows:

\[
\frac{\sum (\text{duration of each power cut} \times \text{number of power cut households})}{\text{total number of users}}
\]

4.2. Power supply reliability
Power supply reliability rate refers to the ratio of the total hours of effective power supply time to the hours of statistical period in the statistical period. The calculation formula of power supply reliability rate is as follows:

\[
(1 - \frac{\text{Average outage time of users}}{\text{statistical period time}}) \times 100\%
\]

The calculation formula of power supply reliability rate (excluding external influence) is as follows:
4.3. Average number of blackouts

The average outage times of power users refer to the average outage times of power users in the statistical period. The calculation formula of the average outage times of power users is as follows:

\[ \frac{\sum (\text{Number of users per outage})}{\text{Total number of users}} \times 100\% \]  \hspace{1cm} (10)

or

\[ \frac{\sum (\text{Number of users per outage}) - \sum (\text{Number of users affected by external factors each time})}{\text{Total number of users}} \times 100\% \]  \hspace{1cm} (11)

The calculation formula of the average number of power outages of users (excluding the power limitation due to insufficient power supply of the system) is as follows:

\[ \frac{\sum (\text{Number of users per outage}) - \sum (\text{Number of power cut users per time})}{\text{Total number of users}} \times 100\% \]  \hspace{1cm} (12)

Function of distribution system reliability statistics:

1. Reliability index such as reliability rate is the necessary condition for power supply enterprises to reach the standard and excellent enterprises to assess.

2. The statistical data of distribution system reliability are fed back to the distribution equipment and power supply department, which can be used as a reference to improve the manufacturing quality of energy equipment and the operation level of distribution system.

3. The reliability index and statistical results guide the power production and construction, and play a guiding role in the whole production process of the existing system and equipment from design to manufacture, installation, commissioning, operation, maintenance and repair.

5. Reliability statistical design

5.1. Data collection

The basic elements of operational reliability data are as follows:

1. Outage users and number
2. Blackout time
3. Power failure causes and associated equipment
4. Estimation of power loss due to power outage

With the above basic information, we can basically calculate the relevant indicators according to the relevant formula. In fact, what needs to be recorded is the number of users, time and power loss caused by power failure in a certain maintenance or accident.

The power outage nature of users is classified as follows:
The main types of power outage include two types of power outage and planned maintenance and outage. Currently, the dispatching operation management module has completely covered two parts of planned maintenance and accident handling, and the graphic integration technology is adopted. Theoretically, it has the function of automatically completing the automatic collection of reliability data. The main difficulty lies in the fact that the current accident handling can't record the detailed operation and complete execution track as planned maintenance[5].

5.2. Method analysis

5.2.1. Data collection scheme of distribution network operation reliability driven by remote signal displacement

If the load or distribution transformer is in the charged state and not charged after operation, it is considered that the load or distribution transformer is out of power, and the user information and time of power loss are recorded. If the load or distribution transformer is not electrified and there is the user information in the power loss record, and the load or distribution transformer is electrified after operation, it is considered that the power supply is restored to the user, and the end time of power failure is recorded. The two operations together constitute the time information of power failure.

Scheme analysis: the scheme starts with the original information of switch displacement, and the data analysis of distribution network operation reliability is triggered by remote signal displacement, so the recorded information is the most accurate; but the scheme separates the causal relationship between the operation of switch equipment, and it is difficult to distinguish the cause of power failure (accident or maintenance) and related information, such as associated equipment.
5.2.2. Data collection scheme of distribution network operation reliability driven by planned maintenance and accident handling

When the dispatcher carries out the operation of planned maintenance module, the system will automatically analyze the load of power loss caused by operation or the start and end time of power loss of distribution transformer, and the start and end time shall be subject to the operation completion time. If the type of outage is planned outage, the specific outage type will be determined according to the maintenance type selected by the user. When the user executes the accident handling steps, the outage information will also be automatically analyzed, and the outage caused by this type of operation will be attributed to fault outage.

Scheme analysis: the scheme is triggered by the planned maintenance and accident handling module, which can automatically classify the causes of power failure and supplement complete power failure information. However, the scheme has higher requirements for planners and dispatchers

1) The reliability statistics are processed in the unit of planned maintenance and accident handling sheet. When the planned maintenance / accident handling is completed, the reliability data statistics will be completed automatically.

2) When the planner draws up the planned maintenance scheme, all the steps that may affect the user's power supply should be invoiced in the graph, including the switch operation, column opening operation, especially the disassembly and erection and jumper operation, and the ticket should also be written in the graph.

3) When an accident occurs, the dispatcher is required to enter the simulation state first, write out all the accident handling steps, and then carry out the accident handling command.

Based on the understanding of the daily operation of the power supply company, it is feasible to automatically analyze the reliability of the planned maintenance. The key of this way is to change the dispatcher's current accident handling mode. The basic steps of accident handling required by this scheme are as follows: when an accident occurs, the dispatcher first creates a new accident handling work order, fills in relevant information, such as trip switch, fault equipment, etc., and then writes out the handling steps (which can be combined with Da module to realize intelligent accident handling) After that, the accident handling and issuing operation will be carried out.

6. Implementation of reliability statistics

After each operation step is completed, the electrification state is analyzed first, and the users whose electrification state changes (including load and distribution transformer) are recorded. If the user changes from electrification to power loss, the user will be cut off, and the user information is recorded, including fault equipment, start time of power failure, scope of power failure, etc. If it is planned maintenance, it is necessary to record the associated maintenance order, maintenance plan and other information. If the user changes from power loss to live, and the information is recorded in the power loss user, the user restores the power supply, records the end time of power failure, and counts the power loss.

For the user's operation requirements, all equipment that may cause power failure operation should be completed through graphic billing, including switch operation, column opening operation, disassembly and assembly and jumper operation.

The statistical accuracy requires that the starting and completion time should be consistent with the actual operation time on site as far as possible. Meanwhile, for the accident handling, a work order similar to the dispatching and maintenance plan should be formed. The work order should have the description of the accident handling process, including the equipment operated in the accident handling process and the accident handling steps. Each step of the work order needs to be converted into a machine recognizable format, and the operation equipment ID, operation type and operation completion time of each step in the accident handling must be clear.
7. Summary
In this paper, through the study of distribution network reliability method based on dispatching operation management, it provides a solution for power supply companies to evaluate the power supply reliability of distribution network, especially the method based on dispatching operation, which greatly reduces the workload of personnel and provides technical support for reliable power supply of distribution network.

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