Reliability Analysis of 10kv Distribution Network Supply

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Abstract. Power supply reliability is a basic indicator of the health of the power system and the level of power company management. Power supply reliability of distribution network is a very important factor to measure the power quality. Through the analysis and research of power supply reliability, we find the relatively weak link of distribution network and make measures to improve the reliability of power supply so as to provide better power quality and create higher social benefits. In this paper, the power supply reliability of distribution network in Nanchang Power Supply Company is taken as the research object. By using gray relational analysis, the reliability factors of distribution network supply can be analyzed to analyze the impact of distribution network on the reliability of distribution network in Nanchang. Finally, the measures to improve the reliability of distribution network are put forward.

1. The background and significance of the research
Reliable medium voltage distribution network can guarantee the power quality of the user's power supply [1]. From the available data, it can be seen that the failure rate of the distribution network in the power system accounts for 80\% [2]. With the gradual development of China's electricity market, more demanding has been improved the reliability of the distribution system [3]. The weakness of distribution network has become a bottleneck in the development of China's power system.

2. Gray relational analysis
System-specific factors that affect the system are ambiguous or that the relationship between the factors is unknown. The system of incomplete information is defined as a gray relation [4]. In the distribution network system, sometimes can’t able to collect the complete information, or there may be omissions in the statistics, based on this, the distribution system can be called a gray system. Therefore, we can use the gray correlation analysis to analysis the distribution network reliability.

Assuming that the development of the two factors in the system is consistent, it indicates that this factor is highly correlated with the development of the system. On the contrary, it indicates the low degree of association [5]. Gray relational analysis is used to analyze the degree to which each factor contributes to the development of the system. The mother sequence is called the reference sequence and used to reflect the results of the system development. The subsequences are called comparison sequences, which reflect the result that each factor changes with time and affects the system development.

2.1. Gray correlation analysis procedure
(1) Determine the reference series and compare series.
Reference series: $x_0(k) = \{x_0(k_1), x_0(k_2), x_0(k_3) ... x_0(k_n)\}$
Compare series: \( x_i(k) = \{x_i(k_1), x_i(k_2), x_i(k_3) \ldots x_i(k_n)\} \)

(2) Non-dimensional treatment of the sequence
The initialization operator is used to normalize the sequence.

\[
x_i(k) d_1 = \frac{x_i(k)}{x_i(1)}
\]  

(2-1)

Use the reciprocal operator for positive correlation.

\[
x_i(k) d_2 = \frac{1}{x_i(k)}
\]  

(2-2)

\( k = 1, 2, \ldots, n \); \( x_i(k) d_1 \) and \( x_i(k) d_2 \) represents the initial value and the reciprocal image of \( x_i(k) \) in the operator respectively.

(3) Find the gray correlation coefficient \( \zeta_i(k) \)
For the reference sequence \( x_0(k) \), there are some comparisons of the sequence \( x_i(k), x_2(k) \ldots x_i(k) \) and the correlation coefficient \( \zeta_i(k) \) for each of these sequences and the reference sequence at each moment is given by the following equation.

\[
\zeta_i(k) = \frac{\min_k \min_k \|x_0(k) - x_i(k)\| + \rho \max_k \max_k \|x_0(k) - x_i(k)\|}{\Delta_0(k) + \rho \Delta(\max)}
\]  

(2-3)

\( \rho \) is the resolution coefficient, generally between 0 to 1 and usually take 0.5. Comparing the absolute difference between each point on the \( x_i(k) \)-curve of the series and each point on the \( x_0(k) \)-curve of the reference series is recorded as \( \Delta_0(k) \).

\[
\Delta_0(k) = \|x_0(k) - x_i(k)\|
\]  

(2-4)

(4) Seeking relevance
The formula for correlation degree is as follows.

\[
\gamma_i = \frac{1}{N} \sum_{k=1}^{N} \zeta_i(k)
\]  

(2-5)

\( \gamma_i \) represents the gray correlation of \( x_i(k) \) to \( x_0(k) \), the closer the value of \( \gamma_i \) is to 1, the better the correlation.

(5) Relevance ranking
Ranking the magnitude of the relevance of each factor is the degree of association of the factors.

3. Analysis of Nanchang county distribution network reliability
According to the above method, AIHC \(-1\) is taken as the feature quantity, denoted by \( x_0(k) \) and the other indexes that can affect the reliability of distribution network power supply are represented by \( x_i(k) \). A and B respectively mean the average power supply radius and the average load rate of the 10kV main line are positively correlated with AIHC \(-1\) and do not need to be converted. \( x_3(k) \) line insulation rate, \( x_4(k) \) ring network rate, \( x_5(k) \) each 10kV line switch characteristics and the relationship between the amount is negatively correlated.

Through the above method is transformed into a positive correlation with the characteristic amount.
Table 1. Nanchang County in 2016 the data

| Project | $x_0$ (k) | $x_1$ (k) | $x_2$ (k) | $x_3$ (k) | $x_4$ (k) | $x_5$ (k) |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| Figure  | 12.66h/household | 11.04km/article | 57.5% | 22.57% | 5.4% | 3.34table / article |

In order to ensure the correlation between each factor and the reliability of power supply, it is possible to avoid some special situations affecting the data of distribution network operation. The values need to be initialized and negatively correlated. Then we can get data’s as follows.

Table 2. After The Initial Value and Negative Correlation Conversion Results

| Project | $x_0$ (k) | $x_1$ (k) | $x_2$ (k) | $x_3$ (k) | $x_4$ (k) | $x_5$ (k) |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| Figure  | 0.860 | 0.922 | 0.985 | 0.474 | 0.766 | 0.880 |

Table 3. Difference calculation result

| Project | $x_0$ (k) | $x_1$ (k) | $x_2$ (k) | $x_3$ (k) | $x_4$ (k) | $x_5$ (k) |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| Figure  | 0.860 | -0.062 | -0.125 | 0.387 | 0.095 | -0.019 |

From the table we can see the minimum difference between the two levels:

$$\Delta_{\text{min}} = \min_{i,k} \min_{i,k} |x_0(k) - x_i(k)| = 0.019$$

From the table we can see the maximum difference between the two levels:

$$\Delta_{\text{max}} = \max_{i,k} \max_{i,k} |x_0(k) - x_i(k)| = 0.387$$

$\rho$ is 0.5, Substituting the formula $\zeta_i(k) = \frac{\Delta_{\text{min}} + \rho \Delta_{\text{max}}}{\Delta_{0i}(k) + \rho \Delta_{\text{max}}}$, the correlation coefficient $\zeta_i(k)$ of each factor is shown in the following table.

Table 4. The correlation coefficient of each factor

| Project | $x_0$ (k) | $x_1$ (k) | $x_2$ (k) | $x_3$ (k) | $x_4$ (k) | $x_5$ (k) |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| Figure  | 0.860 | 0.862 | 0.756 | 0.500 | 0.830 | 0.952 |

And then the above data in accordance with the gray correlation analysis step operation can be associated with the degree of $\gamma_1 \gamma_2 \gamma_3 \gamma_4 \gamma_5$, respectively 0.770, 0.737, 0.767, 0.862, 0.820.

$\gamma_1 > \gamma_2 > \gamma_3 > \gamma_4 > \gamma_5$. After the above gray correlation degree calculation, the factors affecting the reliability index $\text{AIHC} - 1$ of each factor of distribution network equipment level in Nanchang County are sorted by size according to the ring network rate, the average number of segments, the average power supply radius, the line insulation rate, and the average load of main lines rate. The reasons for the above phenomenon are as follows: Previously, the distribution network ring rate of Nanchang County was very low, and the planning of ring network was seldom seen in previous plans.

4. Distribution network planning and construction measures

1 Reasonable use of existing substations and substations to be put into operation, according to their power supply area for rational planning and distribution of power load, but also according to the development needs of load development in time substation, there is a principle of invariant: Substation outlet does not allow cross-regional power supply [6].
2 Rebuilding old equipment and wiring and replacing those old equipment components can greatly reduce the failure rate of the power grid and improve the reliability of power distribution network [7].

3 Improve overhead line insulation rate and cable rate.

4 We can update and replace the on-column switch, then use some high safety factor and operation and maintenance are very convenient SF6 or vacuum switch, etc., to improve the ability of fault repair, and thus can improve the power supply reliability.

5 Improve the power grid to withstand natural disasters, in the design of distribution lines to take into account the safety factor of the line, the tower is still used in the old overhead lines must be promptly replaced or be reinforced.

6 To protect the power supply of important users, such important hospitals as hospitals must ensure the reliability of power supply. Try to choose a short supply radius, low line load substation for power supply, of course, but also to ensure adequate backup power for emergency use.

5. Summary
The reliability of distribution network power supply can fully reflect the management ability in power grid construction and operation and maintenance of power enterprises. The requirements of users for power quality are getting higher and higher with the economic and social development. It is necessary to strengthen the research on the reliability of power supply in distribution network so that the distribution network can be scientifically planned and rebuilt, and the rational use of funds can be made to improve the efficiency of enterprises and save investment resources. Through the study of distribution reliability, we can find out the weak points and problems existing in current distribution network in order to formulate effective measures to enhance the reliability of distribution network.

6. Acknowledgement
This paper was supported by Major Program of National Natural Science Foundation of China (Grant No.51367014). We express our sincere gratitude to the professors and students who provided support and assistance for this paper.

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