*A. Multiple outage scenarios uncertainty modelling.*

During typhoon passage, transmission lines and towers have a failure probability. This probability mainly depends on two factors:the wind load they bear and their own bearing capacity. The wind loads  and  on transmission lines and towers can be calculated using the following empirical equations, respectively:

 (1)

 (2)

where is the wind pressure inequality factor; is the wind speed at the location of the line at time ; is the coefficient of variation of wind pressure height;  is the wire resistance factor;  is the wind load body shape factor; is the wind vibration coefficient; is the outer diameter of the wire;  is the horizontal stall distance of the tower;  is the wind deflection angle;  is the tower shape factor.

Transmission lines, towers can withstand the stress, bending moment has a certain limit, when more than the limit of the line may be broken, down tower accident. When calculating the failure probability of a component under external loads through a function, it can be defined as the difference between the component load and its own strength. When this difference is greater than 0, the component is in an unreliable operating state, and the probability can be expressed as:

 (3)

where  being the stresses on the transmission line or the bending moments in the towers;  is the component's own strength.

The component strengths are generally considered to obey the following normal distribution:

 (4)

where  and  are strength parameters related to lines and towers.

Thus the probability of failure of transmission lines and towers can be expressed as:

 (5)

In this paper, flexible loads are classified into interruptible loads and curtailable loads. Among them, the interruptible load can be dynamically adjusted according to the system scheduling demand.

 (6)

where  is the actual power supplied by the interruptible load of the first node in time period;  is the total amount of interruptible load under the first node at time period .

*B. Post-disaster multi-period stochastic optimisation model*

For curtailable loads, the electricity load under certain nodes can be appropriately adjusted and curtailed after the disaster according to the importance of the loads, the comfort of the users and the dispatch of distributed resources.

 (7)

 (8)

 (9)

 (10)

where is the minimum demand for load curtailment for the -th node in time slot ; is the total amount of load that can be curtailed under the -th node at time period ;  is the adjustment factor for the load that can be curtailed at the ith node under time period ; is the actual supply power of the -th node under time period that can cut the load; The variable denotes the amount of load that can be curtailed by the ith node at time period ; and are the start and end periods of the disaster, respectively; andare parameter that reflects the sensitivity of the curtailable load to external factors.

*C. Probability of time-varying failures of grid elements*

Historical data of Typhoon Limachi show the following. The impact of typhoon location and intensity on the distribution network decreases significantly at T = 12 hours after the disaster occurs. This study focuses on the spatio-temporal impact of typhoons on distribution line states during the period from 0 to T. The calculation is based on a time interval of 1h for the whole time of the typhoon transit. In the calculation example analysis, a 1-hour time interval is used. This interval is applied to analyze the failure probability of grid components during the entire typhoon transit period. Combining (6) with the line design parameters, the spatio-temporal characteristic matrix of the failure rate of distribution lines during the disaster period can be obtained. Taking a portion of the lines as an example, their post-disaster line failure rates are shown in [26].

TABLE 1

Matrix of spatial and temporal characteristics of critical line failure rates

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **work shift** | **L8** | **L9** | **L10** | **L27** | **L28** | **L33** | **L24** |
| **1** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **2** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **3** | 0.000 | 0.204 | 0.131 | 0.000 | 0.000 | 0.000 | 0.000 |
| **4** | 0.423 | 0.642 | 0.398 | 0.000 | 0.000 | 0.000 | 0.000 |
| **5** | 0.000 | 0.000 | 0.000 | 0.216 | 0.537 | 0.000 | 0.000 |
| **6** | 0.000 | 0.000 | 0.000 | 0.184 | 0.243 | 0.168 | 0.000 |
| **7** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.143 | 0.000 |
| **8** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.187 |
| **9** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.614 |
| **10** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.078 |
| **11** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

The disaster duration is short. Without the influence of other non-disaster factors, natural line failures hardly occur. Thus, the failure risk consideration is limited. Failure risk is only considered when the line is within the typhoon wind circle. In other cases, the line failure rate is set to 0. To line 9-10 as an example: t = 3h, the line centre point in the radius of the typhoon impact, according to the probability of distribution of the wind load and the strength of the components, the calculation results in the line in this section of the failure probability of 0.204, in t = 4h typhoon centre is constantly close to the line centre, at this time the line 9-10 failure rate increased to 0.642, and t = 5h, the line outside the range of the typhoon circle, is not subject to the typhoon, even if this time the line is still in the state of disconnection, but by the typhoon impact caused by the line failure rate becomes 0.In this paper, the Monte Carlo sampling simulation method is used. It is based on the spatio-temporal characteristic matrix of line failure rates. The goal is to obtain full-time fault state scenarios during distribution network disasters. Their occurrence probabilities are also obtained.