A transmission line fault rate correction method for meteorological risk sources

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Abstract. A transmission line fault rate correction method for meteorological risk sources is proposed in this paper. Firstly, a complex weather risk source model considering lightning, rainfall, wind, temperature, relative humidity and other meteorological factors is established by introducing the overrun penalty variable weight entropy theory, and the corresponding comprehensive meteorological factors are calculated by using the model; Then, based on the electrical equipment health index model, a transmission line fault rate correction method based on meteorological risk sources is designed. Finally, the effectiveness of the method is verified by simulation experiments.

Keywords. Available transmission capacity; variable weight theory; complex weather risk source;

1. Introduction

In the power market environment, the ATC (Available Transfer Capability) of the power grid can provide system operators and power market participants with detailed information about the use of the power grid to ensure the safety and stability of the power system. This article studies the evaluation model and method of transmission lines. There are a large number of uncertain factors in the actual operation of the power grid, such as the failure of generators, lines, transformers and other components, load fluctuations, and weather changes.

In previous studies, weather factors are mostly used in power grid reliability assessment. Usually based on historical weather data, weather is divided into 2 to 3 typical categories, and the equipment outage probability model under each category is established respectively, and then Calculate the reliability index country of the system. This kind of weather factor modeling method is relatively rough, and the classification of weather conditions is simple, and it is impossible to analyze the impact of weather factors on equipment in real time. For real-time power grid dispatch, it is required to consider meteorological factors more carefully and accurately. For example, literature [1] selects different meteorological evaluation factors and establishes different evaluation levels to comprehensively evaluate the failure rate of transmission lines under the combination of multiple meteorological factors. Literature [2] considered two parts of online monitoring data and meteorological factors, and obtained the real-time line failure rate by referring to the failure probability statistics table and current weather records. The literature [3] divides the weather into normal weather, bad weather and severe weather, respectively calculates the equipment failure rate under three types of weather scenarios, and samples the weather and equipment status in the area based on Monte Carlo simulation to analyze its impact The impact of transmission lines. It can be seen that the real-time comprehensive assessment of weather factors at this stage is still relatively qualitative, and it is difficult to meet the requirements for real-time and accuracy of transmission lines in power grid dispatching operations and power markets.

In summary, based on the real-time weather data provided by the numerical weather monitoring and forecasting system, this paper carefully considers various meteorological factors such as lightning, rainfall, wind, temperature, relative humidity, etc., and establishes a variable weight entropy theory...
based on over-limit penalty. Complicated weather risk source model; combined with non-sequential Monte Carlo simulation and optimal power flow calculation, the power grid ATC is calculated. The model and method proposed in this paper are verified by combining actual weather data in a certain area of Liaoning in my country and an example of IEEE118 node system.

2. Available transmission capacity of the grid

This paper focuses on the power grid ATC calculation method that considers complex weather risk sources. The general idea is: First, the non-sequential Monte Carlo simulation method is used to simulate various uncertain factors of the system. The uncertain factors considered include the uncertainty of weather risk sources. And traditional uncertain factors; then in each certain scenario, the optimal power flow is used to solve the transmission capacity that can be increased from the power supply area to the power receiving area in the system; finally, the ATC probability evaluation index is calculated.

2.1 ATC calculation model based on optimal power flow

In this paper, the AC optimal power flow is used to solve the ATC: on the basis of a given basic power flow, all load nodes in the power supply area, all power generation nodes in the power receiving area, generators and load nodes in other areas maintain the basic power flow unchanged, while increasing the node load of the power receiving area and the generator output of the power supply area will be increased accordingly until any overrun occurs in the system, and the maximum cumulative value of the load of the power receiving area and the generator output of the power supply area at this time is calculated.

2.2 Objective function

The objective function solved by ATC is the cumulative value of the active power output of the power generation node in the power supply area and the active power output of the load node in the power receiving area:

\[
J = \max \left\{ \frac{1}{2}(1 - k) \left[ \sum_{i \in A} (P_{gi} - P^0_{gi}) + \sum_{j \in B} (P_{lj} - P^0_{lj}) \right] \right\}
\]

Among them, \( i \in A \) means \( i \) is the power supply area node; \( j \in B \) means \( j \) is the power receiving area node; \( P_{gi} \) is the generator output of the power supply area; \( P_{lj} \) is the active power output of the load node in the power receiving area; the superscript \( "0" \) represents the basic state; \( K \) is the reflection system. The coefficient of reliability margin is 5% of experience value here.

2.3 Restrictions

2.3.1 Communication flow constraints:

\[
P_{gi} - P^0_{gi} = \sum_{j \in j} U_j U_j \left( G_{i,j} \cos \theta_{i,j} + B_{i,j} \sin \theta_{i,j} \right)
\]

\[
Q_{ci} - Q^0_{ci} = \sum_{j \in j} U_i U_j \left( G_{i,j} \sin \theta_{i,j} - B_{i,j} \cos \theta_{i,j} \right)
\]

Among them, \( j \in i \) means that node \( j \) is a node directly connected to node \( i \); \( U_j \) is the voltage amplitude of node \( i \); \( \theta_{i,j} \) is the relative angle between node \( i \) and node \( j \); \( G_{i,j} \) and \( B_{i,j} \) are the conductance and conductance in node admittance, respectively. Nano; \( Q_{ci} \) and \( Q_{li} \) are the reactive power output and reactive load of the node respectively.

2.3.2 Node voltage constraints:

\[
U^\text{min}_i \leq U_i \leq U^\text{max}_i
\]

Among them, \( U^\text{min}_i \) is the minimum voltage amplitude of node \( i \); \( U^\text{max}_i \) is the maximum voltage amplitude of node \( i \).
2.3.3 Power constraints:

\[
P_{\text{min}}^{\text{Gi}} \leq P_{\text{Gi}} \leq P_{\text{max}}^{\text{Gi}}
\]

\[
Q_{\text{min}}^{\text{Gi}} \leq Q_{\text{Gi}} \leq Q_{\text{max}}^{\text{Gi}}
\]

\[
P_{\text{Lj}}^{\text{min}} \leq P_{\text{Lj}} \leq P_{\text{max}}^{\text{Lj}}
\]

\[
Q_{\text{Lj}}^{\text{min}} \leq Q_{\text{Lj}} \leq Q_{\text{max}}^{\text{Lj}}
\]

Among them, \(P_{\text{min}}^{\text{Gi}} \) and \(P_{\text{max}}^{\text{Gi}} \) are nodes respectively \(i \) The minimum and maximum active power output of the generator; \(Q_{\text{min}}^{\text{Gi}} \) and \(Q_{\text{max}}^{\text{Gi}} \) are nodes respectively \(i \) Minimum and maximum reactive power output; \(P_{\text{Lj}}^{\text{min}} \) and \(P_{\text{max}}^{\text{Lj}} \) are nodes respectively The active base load and maximum load; \(Q_{\text{Lj}}^{\text{min}} \) and \(Q_{\text{max}}^{\text{Lj}} \) are nodes respectively \(i \) Reactive base load and maximum load.

2.3.4 Line flow constraint

\[
-\overline{S}_{i,j} \leq S_{i,j}^{L} \leq \overline{S}_{i,j}
\]

\[
-\overline{S}_{i,j} \leq S_{i,j}^{R} \leq \overline{S}_{i,j}
\]

Among them, \(S_{i,j}^{L} \) and \(S_{i,j}^{R} \) are the apparent power of the first and last power flows of the line \(ij \) respectively; \(\overline{S}_{i,j} \) is the apparent power limit of the line.

3. Research on the Dynamic Mechanism of Transmission Lines Based on Complex Weather

According to the meteorological characteristics of the studied area, relevant meteorological factors are selected to describe the influence of weather conditions on the failure rate of overhead lines. How to quantify weather risk factors more scientifically and objectively is the key. The information entropy theory is introduced here to objectively describe the value of various meteorological factors in real time. The entropy weight theory determines the weight based on the calculated entropy value to determine the effective information provided by each indicator of the system. The greater the difference in the median value of the selected evaluation index, the smaller the entropy value, the more effective information the index provides, and the greater the weight.

The meteorological factors are respectively standardized, entropy and weight calculations to obtain "comprehensive meteorological factors". The specific calculation process is shown in equations (11)-(15). The weather parameters calculated here come from the numerical weather forecast system of the area where the operation is located.

\[
y_{i,j} = \frac{x_{i,j} - x_{i,min}}{x_{i,max} - x_{i,min}}
\]

\[
g_{i,j} = \frac{y_{i,j}}{\sum_{j=1}^{M} y_{i,j}}
\]

\[
e_{i} = -\frac{1}{\ln M} \sum_{j=1}^{M} \left( g_{i,j} \ln g_{i,j} \right)
\]

\[
w_{i} = \frac{1 - e_{i}}{\sum_{i=1}^{N} e_{i}}
\]

\[
C = \sum_{i=1}^{N} w_{i} y_{i,j}
\]

Among them, \(x_{i,j} \) is the meteorological factor value of a certain attribute before the same quantification; \(y_{i,j} \) is the meteorological factor value of a certain attribute after the same
quantification; $x_{i,j\text{min}}$ is the minimum value in $x_{i,j}$; $x_{i,j\text{max}}$ is the maximum value in $x_{i,j}$; $g_{i,j}$ is the ratio, $e_i$ is Multi-attribute meteorological feature entropy value, if $g_{i,j} = 0$, then $g_{i,j} \ln g_{i,j} = 0$, so $e_i \in [0,1]$; $M$ is the total number of months or total time period; $e_x$ is the total number of meteorological factors; $w_i$ is the entropy weight of each meteorological factor; $C$ is Comprehensive meteorological factor, the value range is between 0 and 1. The larger the value, the greater the risk that weather brings to the transmission line, and the greater the impact on the line failure rate.

4. Analysis
Take the actual weather in a certain area of Liaoning as an example to analyze the influence of weather on the failure rate of overhead transmission lines. According to the meteorological characteristics of the area, the three meteorological factors of icing, hail, and snow that rarely occur in the area are ignored in the calculation, and only the relatively common five meteorological factors of lightning, wind speed, rainfall, temperature, and relative humidity are considered. And assume that they correspond to serial numbers $i=1, 2, 3, 4$, and 5. In addition, according to the influence of weather on the line failure rate, it is assumed that the over-limit judgments of various meteorological factors are: $A_{1,4} = 0.4$, $A_{2,6} = 66\text{级}$, $A_{3,3} = 100\text{mm}$, $A_{4,4} = 36.5\text{℃}$, $A_{5,5} = 90%$. Using the weather risk source model mentioned in this article, the weather in the area in the past 5 years is calculated and sorted. The weather risk ranking is shown in Table 1. Wiring diagram of IEEE 118-bus system is shown Fig 1. At the same time, based on the equipment data monitoring of the dispatch control center in the area, the evaluation criteria are formulated as shown in Fig 2.

| Risk level       | Risk value range | Weather status                          | Impact on transmission lines |
|------------------|------------------|-----------------------------------------|------------------------------|
| low              | [0,0.5)          | Normal weather                         | Basically no effect         |
| medium           | [0.5,1.5)        | High temperature and heavy rain         | certain threat               |
| high             | [1.5,3)          | bad weather                            | Greater threat              |
| Extremely high   | $>3$             | extreme weather                         | serious threat               |

Figure 1. Wiring diagram of IEEE 118-bus system
5. In conclusion

This paper establishes a miscellaneous weather risk source model based on the variable weight entropy theory of over-limit penalty, and establishes a modified model that considers the risk sources of complex weather to the line failure rate based on the health index model. Taking the coastal area of Fang as an example, the analysis of the months with high weather risk factors in this area verified that the model can accurately assess the impact of weather factors on overhead transmission lines. On this basis, the system ATC is calculated after taking the complicated weather risk source into consideration. It shows that the weather factor can evaluate the system ATC more accurately, and provide more accurate and real-time electrical information for power field participants and power grid operators.

6. References

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