Transmission line condition assessment technology based on multi-source Parameter Fusion

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Abstract—Aiming at the shortcomings of current transmission line state evaluation, which refers to the isolation of scalars and the low accuracy of evaluation methods, a transmission line state evaluation technology based on multi-source parameter fusion is proposed. This paper collects and selects characteristic data such as line test inspection information, operation and maintenance records, and power grid operating parameters as indicator quantities. The membership function is used to express the distribution state of the index quantity, and the distribution state is used as the data to establish a comprehensive evaluation model of the line operation state based on the long- and short-term memory network. The data tag is used to train the deep network to establish the mapping relationship between index parameters and operation state. Experiments show that the evaluation accuracy of the proposed method is significantly higher than that of the traditional shallow method, which can provide theoretical guidance for the operation and maintenance of overhead transmission lines.

1. Introduction

Transmission line is an important part of power system. Correctly judging the operation state of transmission line is of great significance to improve the security of power system. Transmission line condition assessment technology is a hot issue in current research[1]. At present, there are many theoretical methods of transmission line condition assessment, but there is no unified standard, and there is a subjective influence in determining the weight of each index. To solve this problem, this paper proposes a transmission line state evaluation method based on multi-source parameter fusion evaluation method, establishes the transmission line state evaluation index system, uses the 3-scale multi-source parameter fusion method to determine the weight of each index, and then obtains the comprehensive evaluation result of transmission line state through fuzzy synthesis[2]. The idea and model of deep learning are introduced into the condition evaluation of overhead transmission lines in the main network, and a condition evaluation system of 110 and 220 kV overhead transmission lines based on multi-source parameter fusion is proposed. In this study, the multi-source data is selected as the typical index quantity, the membership function is used as the data marker, and the multi-source parameter fusion model is input as the training sample[3]. The correctness and effectiveness of the system are verified by an example. The system can output operation state level with high accuracy, and can guide manual condition based maintenance and repair.
2. Multi-source parameter fusion evaluation of transmission line state

2.1. Transmission line status multi-source parameter feature acquisition

Import the collected multi-source data into the processing tool, first check the field interpretation, data source, code table and other description information of each data, and then preprocess the data. The main process is as follows: data cleaning mainly includes the scrubbing of default values, format content and logic errors. Aiming at the problems of independent evaluation indexes, various types and complex evaluation system structure of overhead transmission lines, a layered idea is proposed, and a three-layer evaluation system is constructed, as shown in the figure 1.

Fig. 1 Comprehensive evaluation model of transmission line

In the figure, the first layer refers to a scalar, which includes the state quantity of the device unit; The second layer is composed of eight 2-level scalars composed of equipment units; The third layer is the output layer, which uses deep learning algorithm for data mining and data fusion of level 1 and 2 indicators. The key evaluation indexes are extracted by correlation analysis and principal component analysis. The membership function establishes the parameters contained in the function distribution according to expert experience, and represents the output results in the form of set. This paper adopts the function form of the combination of triangle and semi trapezoid, as shown in the figure 2.

Fig. 2 Distribution diagram of membership function of combination of semi trapezoid and triangle

At the same time, the membership functions of four evaluation levels are given.

\[
f_1(x) = \begin{cases} 
1, & x_1, x_1 \\
\frac{x_2 - x}{x_2 - x_1}, & x_1, x < x_2 \\
0, & x_1, x_2 
\end{cases} \quad \text{and} \quad f_2(x) = \begin{cases} 
\frac{x - x_1}{x_2 - x_1}, & x_1, x < x_2 \\
\frac{x_2 - x}{x_3 - x_2}, & x_2, x < x_3 \\
\frac{x_3 - x}{x_4 - x_3}, & x_3, x < x_4 \\
0, & x_4
\end{cases} \quad (1)
\]

Where: \( F_i(x) \) is the membership value corresponding to different \( L_j (j = 1,2,3,4) \) evaluation grades; \( X1 \sim X3 \) are the boundary values of membership functions corresponding to different operating states. In most cases, its value is general, which is taken in this paper \( x_1 = 10, x_2 = 40, x_3 = 70 \). Through the in-depth data mining of multi-source parameter fusion, the transmission line state reliability interval \([P (L_1), P (L_2), P (L_3), P (L_4)]\) can be output. The result is a fuzzy set. In order to obtain more accurate
state evaluation results, the percentile weighting method is used to score the operation state of the transmission line, and the formula is the calculation formula of the operation state grade of the transmission line.

\[
H = \sum_{j=1}^{m} p(t^j) m^j
\]

\[m_j = \begin{cases} 
10, & j = 1 \\
40, & j = 2 \\
70, & j = 3 \\
90, & j = 4 
\end{cases}
\]

Set the data vector set as \(X = \{X_i, i = 1, 2, \ldots, n\}\) the number of data points is \(n\), the sample dimension is \(D\), and the multi-source parameter is \(n\). \(x\) is divided into \(n\) disjoint classes \(C_1, C_2, \ldots, C_{N_c}\), various multi-source parameter centers are \(\overline{M} = \{\overline{m}_r, r = 1, 2, \ldots, N_c\}\). The scoring values corresponding to the status level are shown in the table 1 below.

| Status level | Score value | State description |
|--------------|-------------|-------------------|
| serious      | 0 ≤ H < 20  | Some important values exceed the warning value, and power outage maintenance is required |
| abnormal     | 20 ≤ H < 60 | Some important values are close to the warning value, and maintenance shall be arranged first |
| be careful   | 60 ≤ H < 80 | Some important quantities are missing close to the warning value, and the operation needs to be monitored |
| ordinary     | 80 ≤ H < 100| Each state quantity is within the normal value, and the transmission line operates normally |

In the lightning risk assessment of overhead transmission lines, due to the different influence of each characteristic factor, the weight must be reasonably allocated according to the importance of each factor. When the comprehensive evaluation result of transmission line state is determined, when any level of index is good, general, abnormal or serious state, the comprehensive evaluation result of transmission line state shall be the most serious state.

### 2.2. Evaluation algorithm of transmission line state defects based on multi-source Parameter Fusion

When evaluating the units of the line, it is necessary to study not only the deduction of individual state quantity, but also the total deduction of components. The condition evaluation criteria for components are shown in the table. Under the condition of normal state, the score reduction of each state quantity unit and the total score reduction of components must meet the standards of the table 5. When only one of them meets the criteria in Table 2, it is specified as the state of attention; When the score reduction of each state quantity unit reaches the standard in Table 2, it is specified as abnormal or serious state.

| Line unit                  | state  | normal | be careful | abnormal | serious |
|----------------------------|--------|--------|------------|----------|---------|
| Basics tower               | total  | 15     | 12~25      | 30~33    | 45      |
| Conductor and ground wire  | /      | 10     | /          | 12~25    | 30~33   |
| Insulator string           | <17    | 10     | 17         | 30~33    | 45      |
| Fittings                   | <17    | 10     | 17         | 30~33    | 45      |
| Grounding device           | <25    | 10     | 25         | 30~33    | 45      |
| Ancillary facilities       | /      | 10     | /          | 12~25    | 30~33   |
The evaluation objects include things, strategies, methods, etc. The important feature of extenics evaluation method is that it can not only obtain the level degree of the evaluated object's own state in quantity, but also reflect the dynamic process of the evaluated object from quantitative change to qualitative change to a certain extent. The expression of classical domain is as follows:

\[
M_{0j} = \left( O_{0j}, C, V_{0j} \right) = \left[ \begin{array}{c}
O_{0j} \\
\mathbf{c}_1 \\
\mathbf{v}_{0j1} \\
\mathbf{c}_2 \\
\mathbf{v}_{0j2} \\
\vdots \\
\mathbf{c}_n \\
\mathbf{v}_{0jn} 
\end{array} \right] = \left[ \begin{array}{c}
O_{0j} \\
\mathbf{c}_1 \\
\mathbf{a}_{0j1}, \mathbf{b}_{0j1} \\
\mathbf{c}_2 \\
\mathbf{a}_{0j2}, \mathbf{b}_{0j2} \\
\vdots \\
\mathbf{c}_n \\
\mathbf{a}_{0jn}, \mathbf{b}_{0jn} 
\end{array} \right] \quad (5)
\]

Where, \( O_{0j} \) represents \( j \) levels divided: \( c_n \) (\( n = 1, 2, \ldots n \)) represents the characteristics of state level \( O_{0j} \); \( v_{0jn} \) (\( j = 1, 2, \ldots N \)) is the category of quantity value formulated by \( c_n \) for feature \( c_n \), that is, the category of data obtained by each state level for the corresponding characteristic. The result of condition based maintenance evaluation of transmission line is more in line with the actual requirements.

### 2.3. Implementation of transmission line condition assessment

Short term condition evaluation of overhead transmission line, that is, real-time condition evaluation. According to different meteorological conditions, it can be divided into non disaster weather, disaster weather and extreme disaster weather. Transmission line status level can directly or indirectly represent various information of transmission line status. According to the degree of deterioration, it is divided into grade I, grade II, grade III and grade IV. Based on the characteristics of transmission line condition evaluation and combined with the suggestions of relevant experts of transmission line, the transmission line condition equivalence is divided into "normal", "attention", "abnormal" and "serious", and the specific meanings of deterioration I and II are explained respectively.

| Status type  | Status score | Deterioration level | meaning |
|--------------|--------------|---------------------|---------|
| normal       | 70~100       | I                   | The value is within the specified range, and the line operates normally |
|              |              |                     | If the value is within the specified range and tends to exceed the range, it shall be repaired according to the original plan |
| be careful   | 50~75        | II                  | A small part of the state quantity slightly exceeds the specified range, so it is necessary to monitor it and arrange maintenance |
| abnormal     | 25~50        | III                 | Some important state quantities exceed the specified range and may deteriorate, so maintenance shall be arranged as soon as possible |
| serious      | 0~25         | IV                  | |

The multi-source parameter fusion method mainly studies complex and uncertain systems or chaotic laws, takes data-driven as the core, collects data for specific problems or businesses, and realizes the effective fusion of multi-source data, so as to construct the mathematical analysis and mining model of data and obtain the problem interpretable results. Big data research does not conflict with the traditional theoretical system, and it is also an important part of the scientific research system.
3. Analysis of experimental results

Analysis of experimental results in order to verify the effectiveness of this method, 2000 transmission line cases confirmed to have abnormal defects / faults recorded by the power grid production management system are selected as the training set, and 500 transmission line cases tracked and observed after early warning are selected as the test set to jointly form the sample database of this paper. The learning rate is set to 0.03 and the number of iterations is set to 100. Programming language: Python, programming platform: pycharm, computer CPU: 23ghz, Intel Core i5, memory: 16GB, operating system: osx10.13.6. The index for evaluating the performance of the model is accuracy, which is defined as the number of samples n whose predicted operation state level is consistent with the actual operation state level. The ratio to the total number of samples n is shown in the formula.

\[ A = \frac{N_A}{N} \times 100\% \]  

(6)

Take the current and historical transmission line test and patrol information, operation and maintenance records, and the membership of power grid operation parameters as inputs to predict and evaluate the transmission line status after one week. Further, the Tomek links method is used to randomly select 70% of the samples from the fused data as the training set and the rest as the test set data. The "average temperature", "precipitation", "relative humidity", "average air pressure", "average wind speed" and "lightning recording times" are selected as the input characteristics. The real-time fault status (status) of a certain type of equipment in the same meteorological area "1" indicates that the equipment fails, and "0" indicates that the equipment fails to report) is used as the output to establish a random forest model. The results are as follows:

| Estimate/ True value | fault | Non fault |
|----------------------|-------|----------|
| fault                | 209   | 25       |
| Non fault            | 5     | 1168     |

The figure 3 shows the variation of training set accuracy of three models (LSTM / SVM / BPNN) with the number of iterations.

Fig. 3 Change trend of state evaluation accuracy

The figure 4 shows the accuracy of the three models (LSTM / SVM / BPNN) on the training set and the test set.
It can be seen from the figure that the data sequence of cross entropy loss function is as follows: paper model < SVM < BPNN, that is, the difference between the transmission line state predicted by paper model and the actual state is the smallest, so the weights w and B of paper model reach the optimal value. The evaluation accuracy of the training set is sorted as follows: paper model > SVM > BPNN. The accuracy increases with the number of iterations, and gradually reaches a stable state. The order of evaluation accuracy of training set and test set is: paper model > SVM > BPNN. In terms of the accuracy of the training set, the paper model improves the accuracy of SVM and BPNN by 6.2% and 8.7% respectively, while the paper model improves the accuracy of SVM and BPNN by 3.9% and 8.9% respectively.

### 4. Conclusion

The established transmission line condition evaluation model integrating multi-source data such as line test and patrol information, operation and maintenance records and power grid operation parameters is conducive to formulating timely and effective manual patrol strategy. Through the example analysis and result comparison, the evaluation accuracy based on multi-source parameter fusion network is higher, which is higher than other common evaluation methods, and the gap between the evaluated state reliability is more obvious. In the next step, the architecture improvement and parameter optimization strategy of multi-source parameter fusion model can be studied to further improve the evaluation accuracy and realize the overall state evaluation of power system in a wide range.

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