Research on Reliability of Reporting Power of Wind Power Plant Based on Fuzzy Mathematics

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Abstract. Due to the uncertainty of power generation of wind power plants at a certain time will make it difficult for dispatchers to perform operational scheduling, this paper applies fuzzy mathematics theory to model and combine the historical data of wind turbine generating power and reported power data. The programming was implemented in Qt Creator, and finally the calculated percentage of power reported by the wind power plant at a certain time was calculated. To a certain extent, power system dispatchers have played a supporting role in the power screening of wind power plants. At the end of the paper, 87 wind power plants in a certain province are reported to report the wind power at the same time on the same day. After the algorithm is calculated, the reliability of the reported power of each wind power plant at that time is obtained.

1. Introduction

This paper presents a new method for defining the reliability of wind power [1], mainly for the operating side of the power system. Along with the problems in the actual process, at each time of the day, the wind power plants in each province will report the power generation, how the dispatchers will prioritize screening in this vertical reporting power and how to know in each wind power plant. The proportion of the reported power is worthy of believing and can be used in power planning. For such problems, the credibility of the reported power of the wind power plant is defined as: the credibility of the reported power at a certain point in a wind power plant. Based on the theoretical basis of fuzzy mathematics [2-3], the historical data of each wind power plant is given. The paper gives the reliability model of wind power reporting power. The implementation of the algorithm and the model construction in the Qt Creator 5.11.0 development environment have proved its feasibility.

2. Research on reliability of wind power reporting power

2.1. Wind power reporting power credibility model

With the access of wind power, the reliability of the system is improved, and on the other hand, the probability of power outage of the system is reduced. Wind power reporting power is different from wind power capacity reliability [4-5], the former is more biased towards the running side. Specifically,
the degree of power reported by the wind power plant at each moment can be believed, that is, the percentage of wind power that can be consumed and the reported power in the reported power at each moment. Because the wind power uncertainty causes the reported power to be unequal to the final actual power generation, this calculation needs to be obtained by combining the analysis of historical data. The specific modeling process is as follows:

1° Judging set \( V = \{V_1, V_2, V_3, \ldots, V_{10}\} \), Divide the credibility of wind power into ten levels, Where \( V_i \) indicates the accuracy is level \( i \), The range of values is \((0.1i - 0.1, 0.1i]\).The larger the \( i \), the higher the accuracy;

2° Factor set \( U = \{u_{D1}, u_{D2}, u_{D3}, \ldots, u_{D365}, u_{T1}, u_{T2}, \ldots, u_{T95}, u_{T96}\} \), According to historical data, the factors affecting the credibility of wind power are divided into season (one day) and time period (a certain period of the day), which is only for a specific wind power plant;

3° Definition of multi-factor evaluation matrix, Let \( C_{ij} \) denote the number of all the precisions of the \( i \)-th factor divided into the \( j \)-th grade, and again:

\[
R = \begin{pmatrix}
R_1 \\
R_2
\end{pmatrix}
\]

(2)

Where \( m=365+96=461 \), \( n=10 \). \( R_1 \) and \( R_2 \) are the following matrices:

\[
R_1 = \begin{pmatrix}
R_{1,1} & R_{1,2} & \cdots & R_{1,9} & R_{1,10} \\
R_{2,1} & R_{2,2} & \cdots & R_{2,9} & R_{2,10} \\
\cdots & \cdots & \cdots & \cdots & \cdots \\
R_{365,1} & R_{365,2} & \cdots & R_{365,9} & R_{365,10} \\
R_{365,1} & R_{365,2} & \cdots & R_{365,9} & R_{365,10}
\end{pmatrix}
\]

(3)

4° Set weight \( A = \left( a_1, a_2, \ldots, a_{365}, a'_1, a'_2, \ldots, a'_{96} \right) \), among them \( \sum_{i=1}^{365} a_i + \sum_{j=1}^{96} a'_j = 1 \). And synthetic operations \( M(\oplus,+) \) --The weighted average model (and the operation takes into account that each factor works). Then comprehensively assessed:

\[
B = A \circ R = (b_1, b_2, \ldots, b_{10})
\]

(4)

5° Assume that \( b_m \) is the maximum in \( b_1 \sim b_{10} \), Then the probability that the accuracy level is \( m \) level is determined to be the largest.After normalizing \( B \), let \( \sum_{i=1}^{10} b'_j = 1 \), Then the \( B' = (b'_{1}, b'_{2}, \ldots, b'_{10}) \), probability of being distributed at each level of precision.Credibility is:
\[ P = 0.1 \sum_{i=1}^{10} i \cdot b_j \]  

The above model is only for the data processing of a single wind power plant in a certain year. If it is considered that all wind power plants in each province report data at a certain time every day, real-time updating and data synchronization tracking processing are required, both in software. The effect must be that after the dispatch center receives the data given by several wind power plants at a certain time, the software can immediately give the corresponding credibility. This will facilitate the dispatcher to make decisions.

2.2. Input weight definition

The trick of the algorithm lies in the weight [6-7] given. The dispatcher can add artificial judgment according to the accuracy factor that affects the reported power, so that the result is more accurate and more acceptable.

The definition of weights generally includes the following methods:

1° Expert estimation:

Set factor set \( U = \{u_1, u_2, \cdots, u_n\} \), the existing k experts independently give the weight of each factor \( u_i \) \( (i = 1, 2, \cdots, n) \), the average of the weights of each factor can be taken as its weight, as follows:

\[
 a_i = \frac{1}{k} \sum_{j=1}^{k} a_{ij} \quad (i = 1, 2, \cdots, n) 
\]  

Then the weight is:

\[
 A = \left( \frac{1}{k} \sum_{j=1}^{k} a_{1j}, \frac{1}{k} \sum_{j=1}^{k} a_{2j}, \cdots, \frac{1}{k} \sum_{j=1}^{k} a_{nj} \right) 
\]  

2° Frequency statistics:

Set factor set \( U = \{u_1, u_2, \cdots, u_n\} \), ask relevant experts or staff who are engaged in this aspect and have rich experience (may be set up with the number of people \( k > 30 \) persons), according to the weight distribution research table, each element in the factor set \( U \) is independently proposed to be the most suitable weights.

| Table 1. Weight survey allocation table |
|----------------------------------------|
| Factor \( u_i \) | \( u_1 \) | \( u_2 \) | \( \cdots \) | \( u_n \) | \( \sum \) |
| Weight \( a_{ij} \) | 1 | | | |

According to the weighted distribution questionnaire, a single factor weighting statistical test is performed for each factor \( u_i \). The specific steps are as follows:

1. For the factor \( u_i \) \( (i = 1, 2, \cdots, n) \), find the maximum value \( M_j \) and the minimum value \( m_i \) in its weight \( a_{ij} \) \( (j = 1, 2, \cdots, k) \), ie

\[
 M_j = \max_{1 \leq j \leq k} \{a_{ij}\} \quad m_i = \min_{1 \leq j \leq k} \{a_{ij}\}; 
\]  

2. Appropriately select a positive integer \( a \), and divide \([m_i, M_j]\) into a group according to the principle of equidistance;

3. Calculate the frequency and frequency of the weights falling within each group;
(4) According to the frequency and frequency distribution, the group value of the group in which
the maximum frequency is located is generally the weight $a_j$ of the factor, so that the weight is:

$$ A = \left( a_1, a_2, \ldots, a_n \right) $$

For the calculation of this algorithm, the weight setting is mainly related to the influencing factors.
According to the mathematical model of the appeal, it can be known that the distribution of the
influence precision level in the historical data is the season (some day) and the time period (some
time). Suppose the date of a certain day is $m$ month $d$ day, and it is converted to the xth day of the
year. Corresponding in $A = (a_1, a_2, \ldots, a_{365}, a_1', a_2', \ldots, a_{96})$, Let $a_x = 0.3$, $a_{x-1} = 0.1$, $a_{x+1} = 0.1$; If $x$ is
the first day and the last day of the year, you can change its weight component. Make $a_x = 0.4, a_{x-1} = 0.1$ (or $a_{x+1} = 0.1$). Other dates have a weight of 0. Similarly, when calculating the credibility
of the reporting power at a certain moment, the weight of the time period is increased, and the time in
the vicinity can be appropriately increased, but it must be guaranteed

$$ \sum_{i=1}^{365} a_i + \sum_{j=1}^{96} a_j' = 1. $$

3. Case analysis

The algorithm adopts the development environment of Qt Creator5.11.0 to realize the mathematical
model, and calculates the historical data of a certain province in a certain year to form a multi-factor
evaluation matrix $R$. The province has the largest total system load in this year. The value is 24,328
MW and the number of wind power plants is 87. Experts estimate that the wind power plant's annual
reported power availability ratio is 0.4. The total power generation capacity of the wind power plant is
160,347 MW, but the maximum power generation per unit time is 26 MW per day.

| Table 2. The wind turbine annual power data sheet |
|-----------------------------------------------|
| Month | 1   | 2   | 3   | 4   | 5   | 6   |
|-------|-----|-----|-----|-----|-----|-----|
| Actual power (MW) | 0   | 0   | 0   | 20209 | 15967 | 18517 |
| Reporting power (MW) | 0   | 0   | 0   | 6997  | 5417  | 6475  |
| Month | 7   | 8   | 9   | 10  | 11  | 12  |
|-------|-----|-----|-----|-----|-----|-----|
| Actual power (MW) | 13894 | 17037 | 15581 | 18872 | 20790 | 17152 |
| Reporting power (MW) | 5194 | 5920 | 5204 | 6342  | 7305  | 5846  |

After the algorithm is written, when the input time is 11:20 on July 27, 2018, the calculated
comprehensive evaluation is $B = \{0, 0.0, 0.14, 1.46, 0, 0, 0, 0, 0, 0, 0\}$, it can be seen that the probability that
the accuracy level of the time segment is distributed in three levels is 0.14, and the accuracy in the
fourth level is 1.46. After the normalization process, the final reliability is $P = 0.39125$. This result is
within the allowable range of the prior expert estimate, so this method is feasible.

4. Conclusion

The algorithm design of this paper is based on fuzzy mathematics, and combines all the historical data
of a province in the year to carry out data statistics and modeling. The process is changed from data to
probability, then from probability to frequency, then to level probability, and finally to weight. The
result of the confidence calculation is generated by the synthesis operation. This credibility can be
used by dispatchers to analyze and compare the best results in the daily reported wind turbine power.
Simulation examples show that:

1) The reliability of reporting power of each wind power plant is different at each moment and
there is a difference;
2) The subsequent improvement of the software algorithm is that the real-time update needs to be performed in conjunction with the update of the data, and the corresponding factor evaluation matrix R is automatically updated according to the update of the historical data;

3) When the credibility accuracy is improved, the definition of the weight needs to be measured again. In this paper, when the time is fixed for a certain time, the corresponding weights are set roughly, and the weights corresponding to the time are mainly used, and the neighboring time is supplemented. Synthetic operation. However, this method does not affect the final result too much, and it is also convenient for the dispatcher to make decisions.

References

[1] Zhang Ning, Kang Chongqing, Xiao Jinyu, Li Hui, Wang Zhidong, Shi Rui, Wang Shuai, Wind power capacity credibility research review and prospects [J] Proceedings of the Chinese Society of Electrical Engineering, 2015, 35 (01): 82-94.

[2] Peng X., Wang J., Huan J., Wu F.X., Double-layer clustering method to predict protein complexes based on power-law distribution and protein sublocalization, J. Theor. Biol. 395 (2016) 188-192.

[3] Da-Wei Dong, Ji-Yan Li, Yong-Hong Yang, Xiao-Lei Wang, Jian Liu. Improvements to the fuzzy mathematics comprehensive quantitative method for evaluating fault sealing [J]. Petroleum Science, 2017, 14 (02): 276-285.

[4] Liu Jiebing, Bai Wei, Qin Qiaozhu. Fast reliability algorithm for capacity assessment of wind turbines [J]. Journal of Xi'an Jiaotong University, 2017, 51 (06): 41-53.

[5] Ma Jianwei, Sun Wei, Zhang Jingchao, Liu Chongxu, Zhou Shuangxi. A distributed renewable energy distribution network scheduling strategy based on the prediction of the difference in credibility period [J]. Journal of Power Systems and Automation, 2018, 30 (05): 56-62.

[6] Wenting Ma. Research on Fuzzy Mathematics Model of Teaching Quality Evaluation [A]. Wuhan Zhicheng Times Cultural Development Co., Ltd. Proceedings of 2017 International Conference on Innovations in Economic Management and Social Science (IEMSS 2017) [C]. Wuhan Zhicheng Times Cultural Development Co., Ltd.; 2017: 5.

[7] JIANG Su-na, FANG Jie, LIN Yong. Fuzzy Comprehensive Evaluation of Power Quality of Wind Farm Based on Credibility Theory [J]. Quality and Technology Supervision Research, 2017 (04): 2-10.