A Predicting Method of Power Grid Transmission Line Icing Based on Decision Tree's modified model

Wang Jian, Ma Weiqing, Zhao Xiaolong
The Department of information technology
Shanxi Electric Power Corporation
Taiyuan,China
tywangjian@vip.sina.com

Liang Feifei
Smart grid department
Huada Tianyuan (Beijing) Electric Porwer Tecnaology Co., LTD
Beijing, China
1152653223@qq.com

***Abstract*—Aiming at collapse, disconnection, and ice flash-over problems caused by power grid transmission line icing, this paper proposes a predicting method of transmission line icing. According to historical data and theories of decision tree, calculating out each factor's information entropy, with an overall consideration of each influencing factor's attribute and attribute value and connections between adjacent layers, we pick out the best testing factor as the root note to complete the model. This model has a clear train of thought, at the same time it has high predicting accuracy and efficiency, which provides a strong guarantee for safely running of power grid transmission line.**

Keywords-power grid; icing; decision tree; information entropy; accuracy

I. INTRODUCTION

January of 2008, some areas located at east, mid China suffered from continuous, heavy snow, resulted in power grid transmission line icing[1].Take Guizhou province as an example, since January 12th, 2008, continuous cold rain and snow weather was covered all over the place, about 5029 pieces of transmission lines were destroyed, which is nearly 77% of the total number. It triggered a series of surge tank, disconnection, ice flashover and disaster because of transmission line icing, causing massive destruction to our country's economy.

Based on mechanism of transmission line icing and theories of decision tree, this paper puts forward a set of transmission line ice forecast method. First we analyze icing conditions theoretically, based on ID3 prediction method, we propose a specific decision tree and icing type prediction decision tree; then by giving comprehensive consideration to icing factors' attributes and attribute values as well as connections between each layer of the decision tree, an improved MID3 predicting method is proposed. Finally in subsequent practice, we can improve the accuracy and validity of the model.

II. ICING MECHANISM

Icing is a comprehensive physical phenomenon influenced by factors such as micro-weather, tiny terrain changes in temperature, humidity, air convection, circulation and wind[2].

A. *Influencing factors of icing*

Meteorological factors that influences icing include temperature, air humidity, wind speed, wind direction, supercool water droplet's diameter, etc. Related research achievements at home and abroad are slightly different, here is a general description:

1) *Air temperature:* General temperature that may cause icing is -20~ 0℃, while the most likely temperature is -6~ 0℃, if the temperature is too low, supercool water droplets turn into snow, then there will be no chance of icing, however, if air humidity hits the required value, still it is likely to ice despite the temperature is -40~-21℃.

2) *Air humidity:* Humidity (in this paper it refers to relative humidity), usually more than 85%, not only it is easy to cause icing, but also to form glaze. If air humidity reaches more than 90%, then the chances are massively increased.

3) *Wind speed and wind direction:* Possible wind speed of icing is 0~10m/s, at 0~6m/s it is very likely of icing. In comparison with other factors, wind speed especially affects the formation of granular rime.

4) *Supercooled water droplets: S*upercooled water mainly influences the type of icing. Droplet which is about 10 ~40μm will cause glaze; when it comes to rime ice, water droplet is 1~20μm; for mixed rime, the diameter is 5 ~ 35μm.

5) *Clotting height:* clotting height means the air freezing level based on the ground, it is the decisive factor for high altitude mountain icing.

B. *Attribute classification*

Based on the information above, icing prediction model should take factors such as weather, temperature, humidity, wind speed into account. These four factors restrict each other, and they are strongly connected.

To simplify the model, we categorize the factors into different attributes, the result is listed below:

1) *Weather is divided into: sunny, foggy, rainy, snowy.*

2) *According to temperature range, it is divided into: very cold (-40~-21 ℃), cold (-20~ 0 ℃) two interval;*

3) *Humidity in 85% - 90% is normal, and large for over 90%;*

4) *When the wind is blowing at the speed of 0~6m/s, we call it breeze, 6~10m/s as strong breeze.*

Based on result above and relevant material in 2-1, we work out the following attribute table 1:

TABLE I. ATTRIBUTE CLASSIFICATION

Attribute classification					
number	weather	temperature	humidity	wind speed	possibility of icing
1	sunny	very cold	normal	breeze	impossible
2	sunny	very cold	normal	strong breeze	impossible
3	sunny	very cold	large	breeze	possible
4	sunny	very cold	large	strong breeze	possible
5	sunny	cold	normal	breeze	possible
6	sunny	cold	normal	strong breeze	possible
7	sunny	cold	large	breeze	very likely
8	sunny	cold	large	strong breeze	possible
9	rainy	very cold	normal	breeze	impossible
10	rainy	very cold	normal	strong breeze	impossible
11	rainy	very cold	large	breeze	possible
12	rainy	very cold	large	strong breeze	possible
13	rainy	cold	normal	breeze	very likely
14	rainy	cold	normal	strong breeze	possible
15	rainy	cold	large	breeze	very likely
16	rainy	cold	large	strong breeze	possible
17	foggy	very cold	normal	breeze	impossible
18	foggy	very cold	normal	strong breeze	impossible
19	foggy	very cold	large	breeze	possible
20	foggy	very cold	large	strong breeze	possible
21	foggy	cold	normal	breeze	very likely
22	foggy	cold	normal	strong breeze	possible
23	foggy	cold	large	breeze	very likely
24	foggy	cold	large	strong breeze	possible
25	snowy	very cold	normal	breeze	impossible
26	snowy	very cold	normal	strong breeze	impossible
27	snowy	very cold	large	breeze	possible
28	snowy	very cold	large	strong breeze	possible
29	snowy	cold	normal	breeze	very likely
30	snowy	cold	normal	strong breeze	possible
31	snowy	cold	large	breeze	very likely
32	snowy	cold	large	strong breeze	possible

III. ID3 PREDICTION METHOD

ID3 algorithm is firstly put forward by Quinlan. It is universally recognized as the most widely used decision tree learning algorithm.

Suppose a data sample set as X, our goal is to divide it into n different parts. Assume $C_i$samples belong to the i'th category, and the total data number is |X|, so the possibility of a certain data that it happens to belong to the i'th category is $P(C_i) \approx \frac{C_i}{|X|}$, and the degree of uncertainty of C (i.e., information quantity) is :

$$H(X,C)=H(X) - \sum_i^n p(C_i)\log_2 p(C_i)$$

If we choose attribute a (suppose attribute a has m different values) for testing, and the degree of uncertainty (i.e., condition entropy) is:

$$H(X/a) = -\sum_{i=1}^n \sum_{j=1}^m p(C_i, a = a_j)\log_2 p(C_i, a = a_j)$$

So what attribute a provides for classification equals to:

$$I(X, a)=H(X)-H(X/a)$$

In this equation, I(X, a) stands for choosing attribute. It represents the falling degree of classification properties, in order to get accurate result, we should choose the biggest I(X, a) attribute as classification properties[3].

A. *Icing prediction decision tree based on ID3*

As it is depicted in tab1-1, the possibility of icing can be divided into three types: impossible, possible, and very likely. According to formula above, information expectations of a given sample T(tree) is:

$H(T)=-8/32\log_2 8/32-7/32\log_2 7/32-17/32\log_2 17/32=1.46$

Value(weather)={sunny, rainy, foggy, snowy}, sunny={1,2,3,4,5,6,7,8}, in which possible:5, 2 for impossible, and the last one is very likely, so:

$$H(T/weather)=-\sum_{1}^{n} p_i \log_2 p_i$$

$=8/32(-5/8\log_2 5/8-2/8\log_2 2/8-1/8\log_2 1/8)+8/32(-2/8\log_2 2/8\times 2-4/8\log_2 4/8)\times 3$

$=1.45$

Applying the same method, we get:

Temperature expectation entropy is 0.745; humidity expectation entropy is 1.145; wind speed expectation entropy is 1.179;

Based on formula :

$$I(X,a)=H(X)-H(X/a)$$

I(T, the weather) = 1.46-1.45 = 0.01

I (T, temperature) = 1.46-0.745 = 0.715

I (T, humidity) = 1.46-1.145 = 0.315

I (T, wind speed) = 1.46-1.179 = 0.281

From calculation above, we can see that H(T/temperature) is the smallest, thus I(T, temperature)is the largest, so we take temperature as the root node, by using the recursive method in sequence, we get the following binary tree diagram as shown in Fig 1:

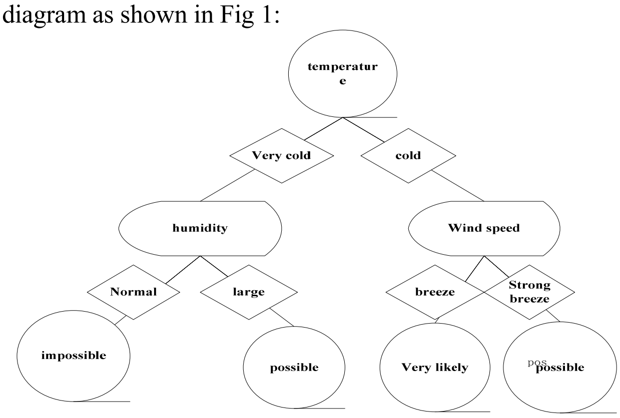

Figure 1. Icing prediction decision tree based on ID3

B. *Icing type decision tree based on ID3*

According to icing forming conditions and properties, icing type can be divided into A, B, C, D, E five different types[4].

A: glaze ice, it usually forms during the freezing rain period and in low altitude area when the wind is quite strong, its density is very high, glaze ice is the primary stage of mixed glaze.

B: mixed glaze, when the temperature is lower than freezing point, and the wind is fierce, there forms the mixed glaze. If transmission line exposes too long in moisture air, it is most likely to form mixed glaze.

C: soft rime, its formation is under circumstances as lower cloud contains subcooled water drops in extremely low temperature.

Type D and E are rime, snow or rime is formed on the surface of cold thing when air moisture meets something under 0℃. Compared with other types of icing, it has the tinniest effect on transmission line.

Combine the information above and relevant data integration, we get the table below:

TABLE II. TAB 1-2: ICING TYPE CLASSIFICATION

icing type				
weather	humidity	temperature	wind speed	type
rainy	＞85%	-5~0℃	1~10m/s	glaze ice
sunny	＞86%	-20~-11℃	6~10m/s	mixed glaze
foggy	＞87%	-8~-3℃	5~10m/s	soft rime
foggy	＞88%	-20~-11℃	1~10m/s	rime
snowy	＞89%	-15~-6℃	1~10m/s	snow

According to the last section on ID3 prediction method and the table above, we can get the following decision tree of icing type:

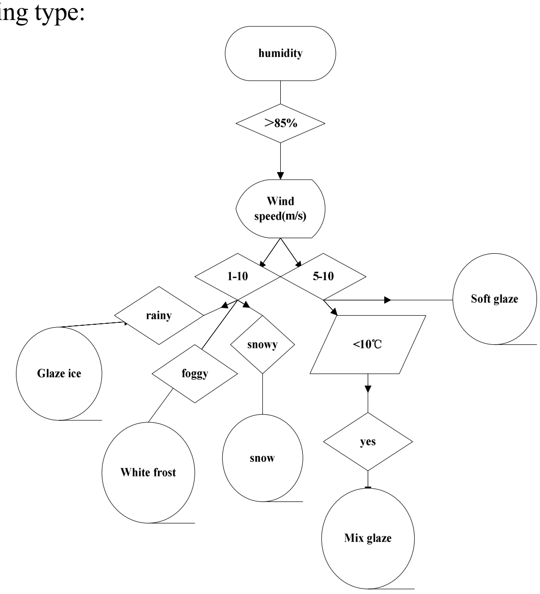

Figure 1. Figure 2. Icing type predicting decision tree based on ID3

IV. ADVANCED ID3 PREDICTION METHOD

The conventional ID3 focuses on the attribute of influencing factors but ignores attribute value, and it neglects the connection between adjacent layers of the decision tree, so comprehensively speaking, this is not the most accurate decision tree. In order to optimize this method, we make a comprehensive consideration of both the attribute value and attribute of influencing factor, then take the connection between different layers of the decision tree into account, then we get the advanced ID3 prediction method, specifically as follows:

As we noted above, we divide temperature into two different kinds: very cold and cold, when we choose very cold as a testing root, each attribute's information entropy is:

I (T, very cold=1 I(T, cold)=0.522+0.467=0.989
I (T, normal)=0 I(T, large)=0
I (T, breeze)=0.5 I(T, strong breeze)=0.5
I (T, sunny)=0.5 I (T, rainy)=0.5
I (T, foggy)=0.5 I (T, snowy)=0.5

I(T, normal)=I(T, large)=0, so we choose humidity as the root note, applying traditional ID3 method, here in the figure below is the final icing prediction decision tree:

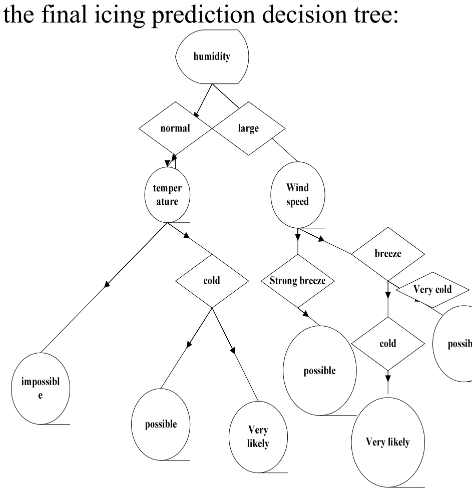

Figure 3. Advanced icing prediction decision tree

This algorithm is an advanced algorithm of ID3, by giving an overall consideration of influencing factor's attribute and attribute value, it overcomes the defects of ID3. Moreover, this algorithm deeply analyzes the connection between adjacent layers of the decision tree, which ensures the accuracy of the predicting method.

V. CONCLUSION

For a long time, transmission line icing prediction is a blind spot as well as an urgent problem remained to be solved. To solve this problem, this paper considers influencing factors such as weather, temperature, humidity and wind speed, based on the modified ID3 method, calculate out each influencing factor's information entropy, choosing the factor which contributes the most for predicting as the root note to generate the decision tree, it provides a feasible, simple, clear method for icing prediction. Of course, due to different local climatic conditions, geographical conditions, this method has to do some adjustment. And our next step is to perfect this method.

REFERENCES

[1] Du Yunying, Xing Jun, et al. A reason and strategy research of southern icing disaster, Jiangsu electrical engineering, 2008, 27(6):14-17.

[2] Yan Tongxi, et al. Transmission line icing meteorological parameter analysis, Mechanical management and development, 2006, (5):51-52.

[3] Pi Zhixian, Power load forecasting research based on decision tree, North China electric power university master degree thesis, 2011.

[4] Liao Xianglin, Transmission line icing property classification and density, Electric power construction, 1994, (9).

[5] Tan Guanri, several microclimate discussion on transmission line icing [J], Acta Meteorologica Sinica, 1982.