Research on Ice Types Identification of Transmission Line Based on Micro-meteorological Parameters

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Abstract— **Transmission line icing seriously endangers the safe and stable operation of the power grid. Different ice types have different degrees of harm to the power grid and are related to anti-icing and deicing work. Firstly, based on the online monitoring images and meteorological parameters of the transmission lines in southern China, the micro-meteorological database of ice types is constructed. Then, the micro-meteorological characteristics of different ice types are studied, including temperature, humidity, and geographical location distribution characteristics. Finally, the K-Nearest Neighbors (KNN) classification algorithm is proposed; the average temperature, humidity, and wind speed of three consecutive days are used to identify the four ice types, which provides a basis for the decision-making of anti-icing and deicing of transmission lines.**

Keywords— ***Transmission line; ice types; micro-meteorological parameters; database; KNN classification algorithm***

I. Introduction

Transmission line icing seriously threatens the safety of the transmission line and causes heavy losses[1]-[4]. Different ice types have different degrees of harm to the power grid. Hence, the study of transmission line ice types is of great significance for the safe and stable operation of the power grid.

Ice types of transmission line are usually divided into glaze, rime, mixed rime, wet snow, etc.[5]. The formation conditions of ice types are different. Reference[6]-[7] studied the corresponding relationship between environmental conditions and icing density to judge the ice type. However, the formation conditions and density range of different ice types are not strictly defined, so it is impossible to accurately distinguish ice types. Reference[8]-[11] realized the recognition and judgment of ice types of transmission line based on the characteristics of icing images. However, because the image quality is poor and the utilization rate is low, it is difficult to grasp the image features and identify the ice types only by expert experience judgment and manual design features.

In this paper, based on the icing images and meteorological data of the online monitoring system for transmission line icing, the micro-meteorological database of ice types is constructed. The micro-meteorological characteristics of different ice types are studied, including temperature, humidity and geographical location distribution. The K-Nearest Neighbors (KNN) classification algorithm is proposed to identify the ice types by using the micro-meteorological data for three consecutive days.

II. Methods and Experiments

A. Construction of Micro-meteorological Database of Ice Types

The construction of the micro-meteorological database includes manual labeling of ice types, data processing of micro-meteorological parameters and multi-source data fusion.

1) *Manual Labeling of Ice Types:* The ice types are divided into glaze, rime, mixed rime, and wet snow, as in [12]. The customized annotation tool is used to label the ice types of icing images. The typical images of four ice types are shown in Figure 1.

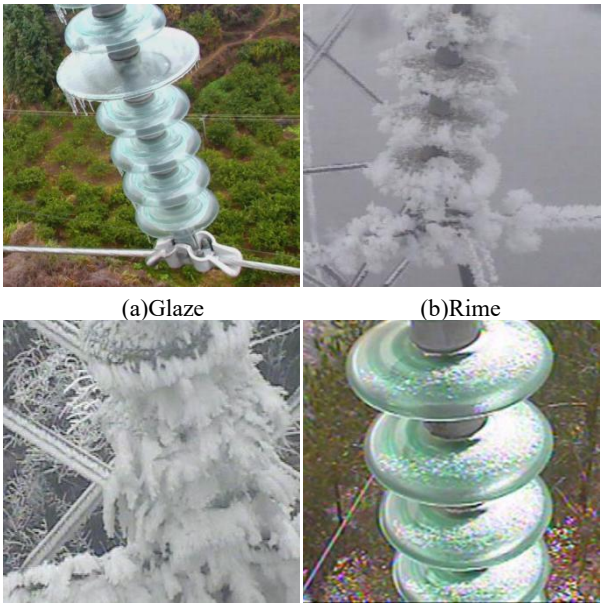
2) *Data Processing of Micro-meteorological parameters :* Data processing such as filling in missing values and deleting duplicate values for micro-meteorological parameters. The meteorological parameters include the average temperature (T_DAY1), average humidity (H_DAY1), and average wind speed (W_DAY1) two days before image shooting; the average temperature (T_DAY2), average humidity (H_DAY2), and average wind speed (W_DAY2) of the day before image shooting; and the average temperature (T_DAY3), average humidity (H_DAY3), and average wind speed (W_DAY3) on the day of image shooting.

3) *Multi-source Data Fusion:* The ice types, micro-meteorological parameters and terminal geographic location(GEO_LO) are fused to construct the micro meteorological database of ice types.

All parameters of the database are shown in Table I.

TABLE I. All parameters of the database

ICE_TYPE	IMAGE_TIME	T_DAY1	H_DAY1
W_DAY1	T_DAY2	H_DAY2	W_DAY2
T_DAY3	H_DAY3	W_DAY3	GEO_LO



(a)Glaze (b)Rime

(c)Mixed rime (d)Wet snow

Fig. 1 Typical images of ice types.

B. Analysis of Micro-meteorological Characteristics of Ice Types

The study of micro-meteorological characteristics of ice types includes the distribution characteristics of temperature, humidity and geographical location.

1) *Distribution of Temperature and Humidity:* The distribution characteristics of the average temperature and average humidity of glaze, rime, mixed rime, and wet snow for three consecutive days are respectively counted and analyzed by box plot.

2) *Distribution of Geographical Location:* According to the geographical coordinates of terminal, the geographical location distribution of ice types is analyzed by using the dot distribution map.

C. Recognition of Ice Types Based on KNN

Recognition of ice types based on KNN includes composition of sample data set, establishment of KNN model and evaluation of recognition precision. The general technical route is shown in Figure 2.

1) *Composition of Sample Data Set:* The total number of samples is 1452. One sample data includes nine eigenvalues and one target value. Nine eigenvalues are nine meteorological parameters in the micro-meteorological database of ice types, and one target value is the ice type.

2) *Establishment of KNN Model:* The sample data set is divided into training set and testing set according to 9:1. The training set is used for model training and the testing set is used for model verification. The numbers of ice type samples of training set and testing set are shown in Table II.

3) *Evaluation of Recognition Precision:* The ice type predicted by KNN model is compared with the actual ice type in the testing set, and the precision[13] is selected as evaluation index of model performance.

TABLE II. THE NUMBER OF SAMPLE DATA

	Glaze	Wet snow	Rime	Mixed rime
Training set	158	151	644	353
Testing set	18	17	72	39

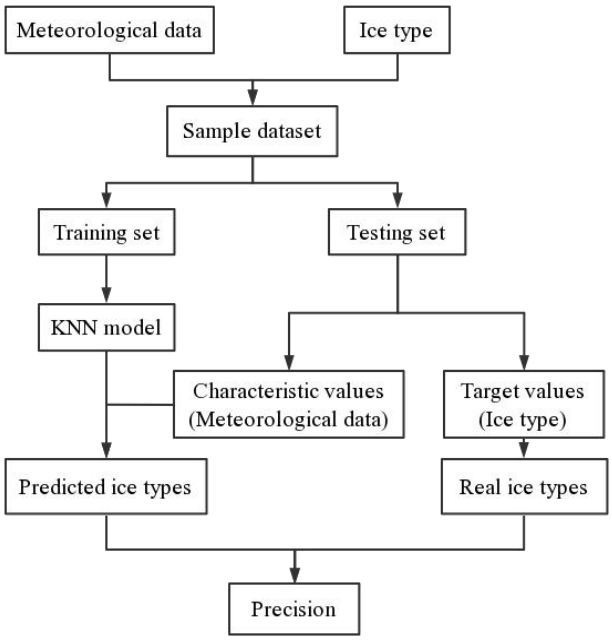


Fig. 2 Technical route for identification of ice types.

III. RESULTS AND DISCUSSION

A. Micro-meteorological Characteristics of Ice Types

1) *Temperature Distribution:* The box plot of temperature distribution for three consecutive days is shown in Figure 3. The mean of average temperature is shown in Table III. The results show that the T_DAY1 formed by ice types have the trend, which is glaze > rime > wet snow > mixed rime, and the T_DAY2 and T_DAY3 is glaze > wet snow > rime > mixed rime.

TABLE III. THE MEAN OF AVERAGE TEMPERATURE (℃) OF FOUR ICE TYPES FOR THREE CONSECUTIVE DAYS

	Glaze	Wet snow	Rime	Mixed rime
T_DAY1$_{mean}$	0.39	-2.15	-1.42	-3.54
T_DAY2$_{mean}$	-1.28	-2.57	-2.73	-3.97
T_DAY3$_{mean}$	-2.07	-3.16	-3.41	-4.02

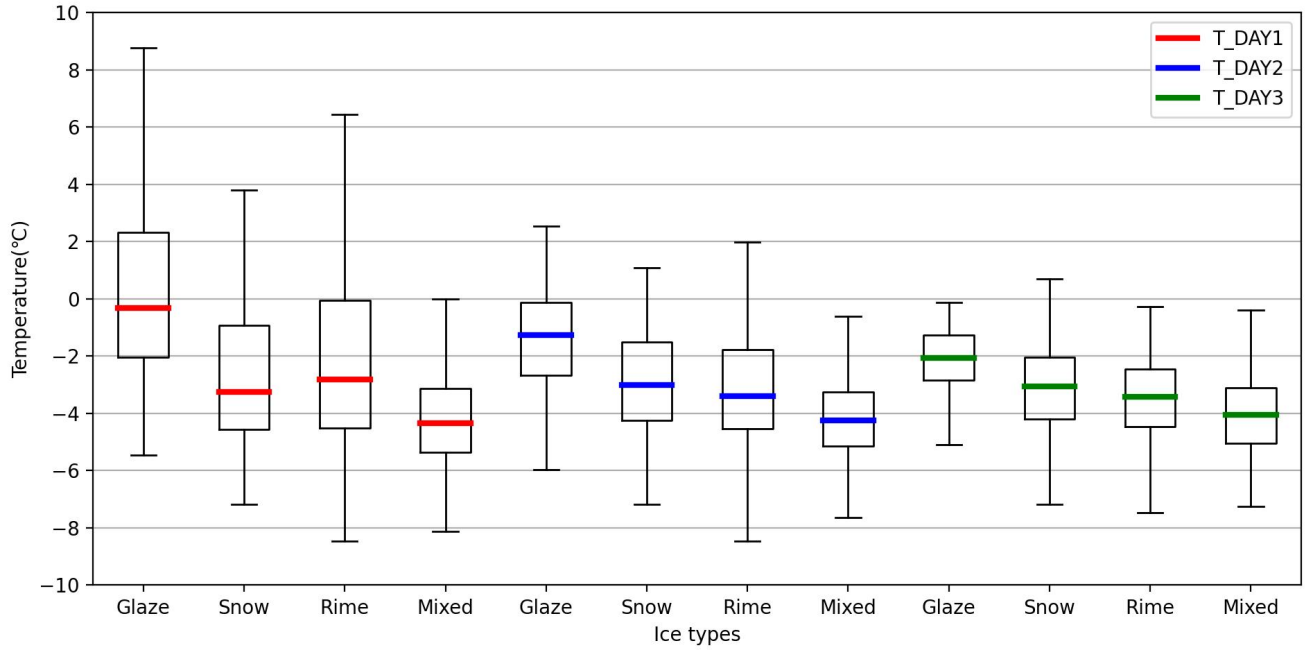


Fig. 3 Box plot of temperature distribution for three days

2) *Humidity Distribution:* The box plot of average humidity distribution for three consecutive days of the four ice types is shown in Figure 4. The mean of average humidity is shown in Table IV. It can be seen from the box plot that the average relative humidity of the four ice types are more than 80% for three consecutive days, and most of them are between 95% and 100%. According to the mean, the relative humidity formed by wet snow is the highest, the humidity formed by mixed rime is the lowest, and the humidity of glaze and rime are in between and not much different.

TABLE IV. THE MEAN OF AVERAGE HUMIDITY (%) OF FOUR ICE TYPES FOR THREE CONSECUTIVE DAYS

	Glaze	**Wet snow**	**Rime**	**Mixed rime**
H_DAY1$_{mean}$	91.6	94.6	90.9	90.2
H_DAY2$_{mean}$	92.3	94.2	92.3	90.7
H_DAY3$_{mean}$	91.2	95.3	93.0	90.8

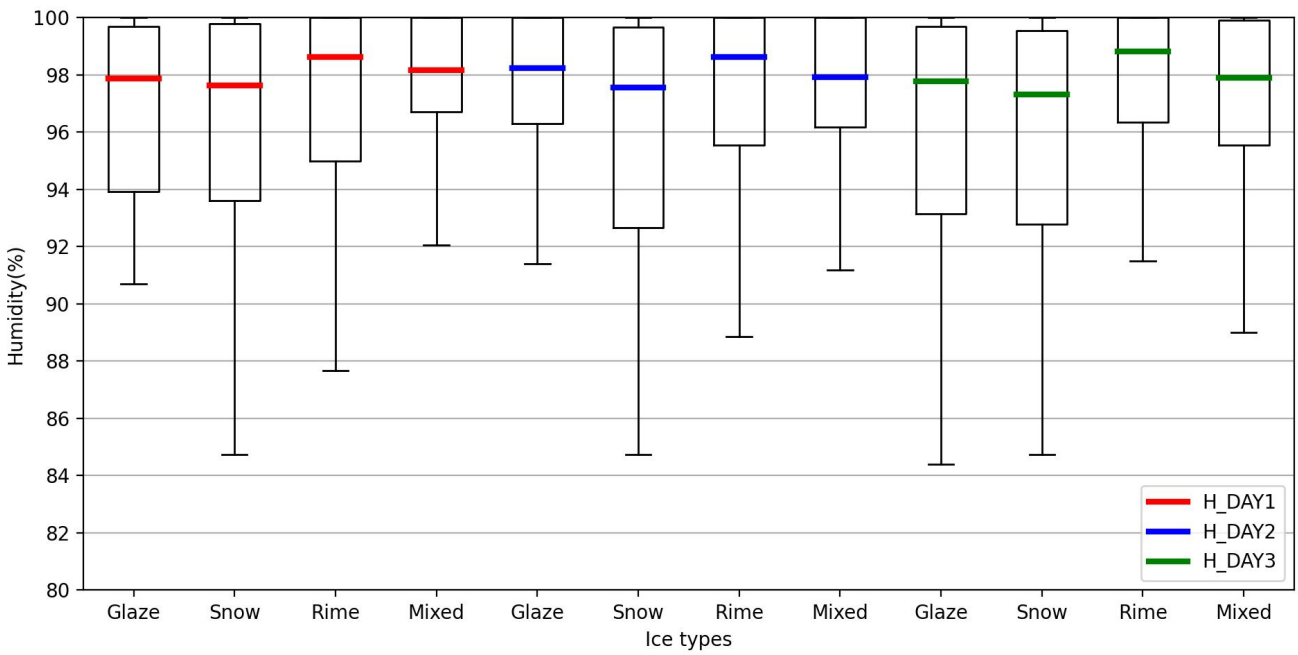


Fig. 4 Box plot of humidity distribution for three days.

3) *Geographical Location Distribution:* The dot distribution map of the geographical location of four ice types is shown in Figure 5. The result shows that the icing of transmission lines in southern China is mainly concentrated in Guizhou Province and Yunnan Province, and the ice types are mainly rime and mixed rime. There is relatively little ice cover in Guangxi and Guangdong Province, with more rime in Guangxi and more glaze in Guangdong. There is no ice cover in Hainan Province and the wet snow is almost concentrated in Guizhou.

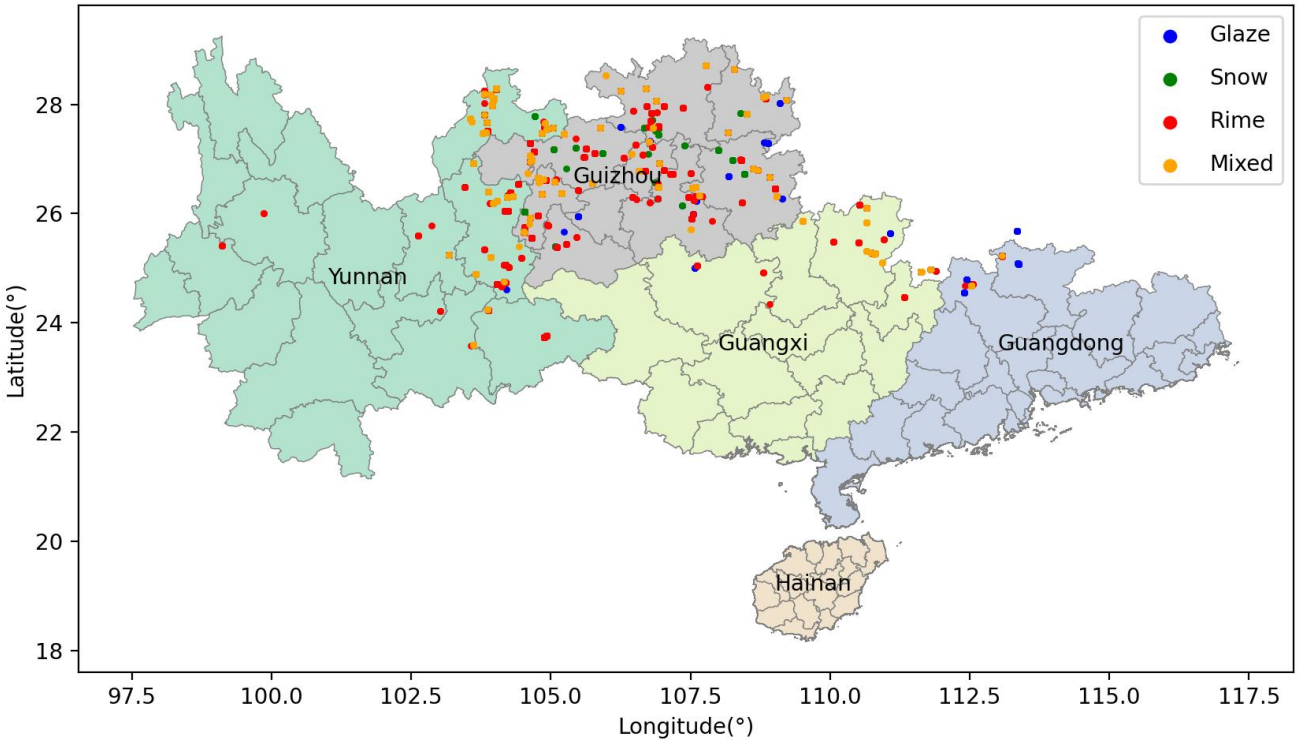


Fig. 5 Dot distribution map of ice types in Southern China.

B. KNN Recognition of Ice Types Based on Micro-meteorology

The precision of KNN to identify ice types is shown in Table V. The result shows that the precision of different ice types is different, the precision of rime and mixed rime is higher than that of glaze, the precision of glaze is higher than that of wet snow, and the precision of rime and mixed rime is almost equal. The reasons are analyzed as follows：

1) The low resolution of the icing image itself leads to inaccurate manual labeling.

2) The numbers of ice type samples are unbalanced, with less glaze and wet snow.

3) Glaze features are more obvious than wet snow, so it is easier to distinguish when labeling.

4) Due to the prolonged low-temperature rain and snow weather, rime is easy to develop into mixed rime so than it is difficult to distinguish by the human eyes.

TABLE V. THE PRECISION OF KNN TO IDENTIFY ICE TYPES

	Glaze	**Wet snow**	**Rime**	**Mixed rime**
Precision	72.2%	64.7%	76.9%	76.4%

IV. CONCLUSIONS

In this paper, the micro-meteorological database of ice types is constructed; the micro-meteorological characteristics of four ice types are analyzed; the accurate identification of ice types is realized by using micro-meteorological data, which provides a basis for the decision-making of anti-icing and deicing of transmission lines.

ACKNOWLEDGMENT

This research is supported by the Big Data Analytics and artificial intelligence application of power transmission line icing in southern China (Technology Project No. 066600KK52190063), and Icing monitoring device diagnosis and short-term prediction based on spatiotemporal characteristics (Technology Project No. SEPRI-K196006).

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