A Research of Icing Forecasting Algorithm Using Genetic Algorithm and Fuzzy Logic

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1. Introduction

Since January 2008, many provinces in southern China suffered a large area, long sleet freezing weather, which leading to a number of transmission line accidents, such as break line, pole collapse, tower collapse, ice flashover and ice-shedding and so on. A large area of the grid in a paralyzed state and the direct economic losses of more than 100 billion yuan.

1. Introduction

Therefore, it has great engineering practical significance to ensure the safe operation to develop a transmission line online monitoring system, remote real-time monitoring lines icing conditions, establish icing forecasting algorithm which based on monitoring data, and provide ice alarming .

1. Introduction

Ice growth prediction model was established previously by the author , the dynamic and static performance and control effect of fuzzy system are decided by the fuzzy rules and correct choice of the membership functions. If the fuzzy rules can't cover all cases, the fuzzy system control effect is likely to be poor. And it is difficult to judge the system control effect .

GA (*genetic algorithm*) is a global search algorithm, according to a set of control effect of fitness function evaluation algorithm, less dependence on the problems, so that can avoid falling into local optimum, and very suitable for optimization design of fuzzy control system.

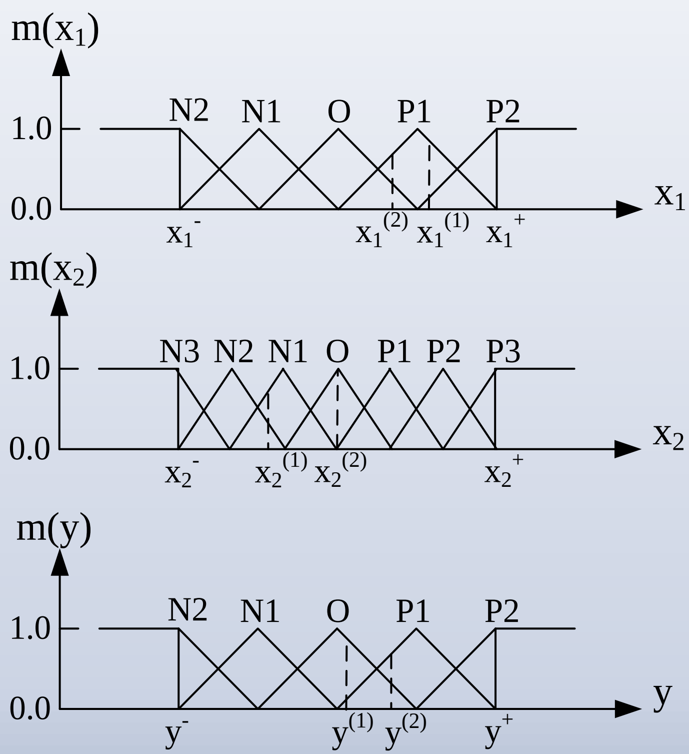
1. Introduction

◆a combined fuzzy rules base was established by using a learning algorithm combined with the expertise experience fuzzy rules in the field data.

◆ GA (*genetic algorithm*) is used to optimize the parameters of icing forecasting model, such as the input-output domain fuzzy division; combined fuzzy rules base and membership function, etc.

◆the monitoring data acquired from transmission line online monitoring system on Guizhou Power Grid of China in 2014 was selected to compare the predicted effects of icing forecasting model before and after optimization.

2. Establish a combined rules base



$$(x_1^{(1)},x_2^{(1)};y^{(1)}),\ (x_1^{(2)},x_2^{(2)};y^{(2)}),\ldots \quad (1)$$

Input: $x_1 \in [x_1^-,x_1^+]\ x_2 \in [x_2^-,x_2^+]$

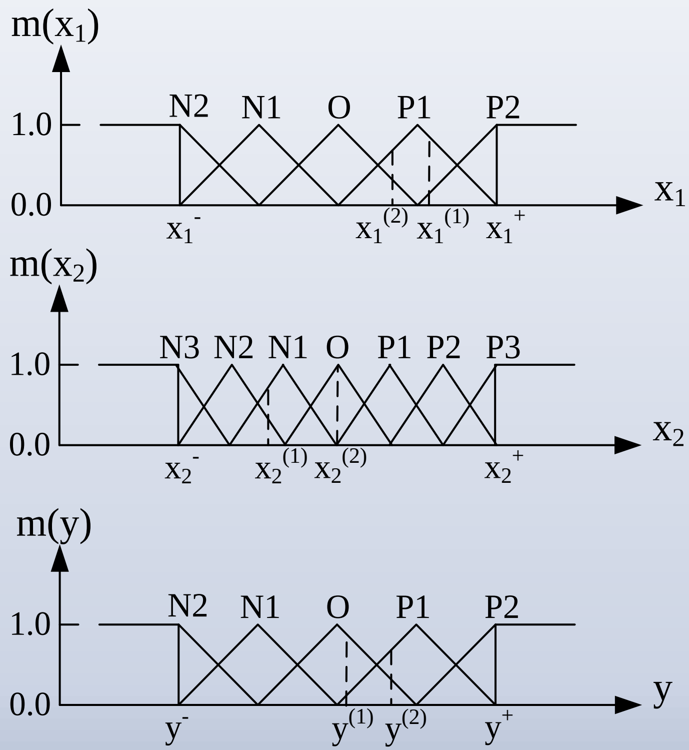
Output: $y \in [y^-,y^+]$

$(x_1^{(1)},x_2^{(1)};y^{(1)}) \rightarrow [x_1^{(1)}($ 0.8 in P1,max$)$, $x_2^{(1)}($ 0.7 in N1,max$);y^{(1)}($0.9 in O, max$)] \rightarrow$ Rule 1;

$(x_1^{(2)},x_2^{(2)};y^{(2)}) \rightarrow [x_1^{(2)}($0.6 in P1,max$)$, $x_2^{(2)}($ 1 in O, max$);y^{(2)}($0.7 in P1, max$)] \rightarrow$ Rule 2.

Fuzzy partition of x1、x2、y universe

2. Establish a combined rules base



Fuzzy partition of x1、x2、y universe

$$D(Rule)=m_A(x_1)m_B(x_2)m_C(y) \quad (2)$$

$$D(Rule1) = m_{P1}(x1)\ m_{N1}(x2)\ m_O(y) = 0.8\times 0.7\times 0.9=0.504 \quad (3)$$

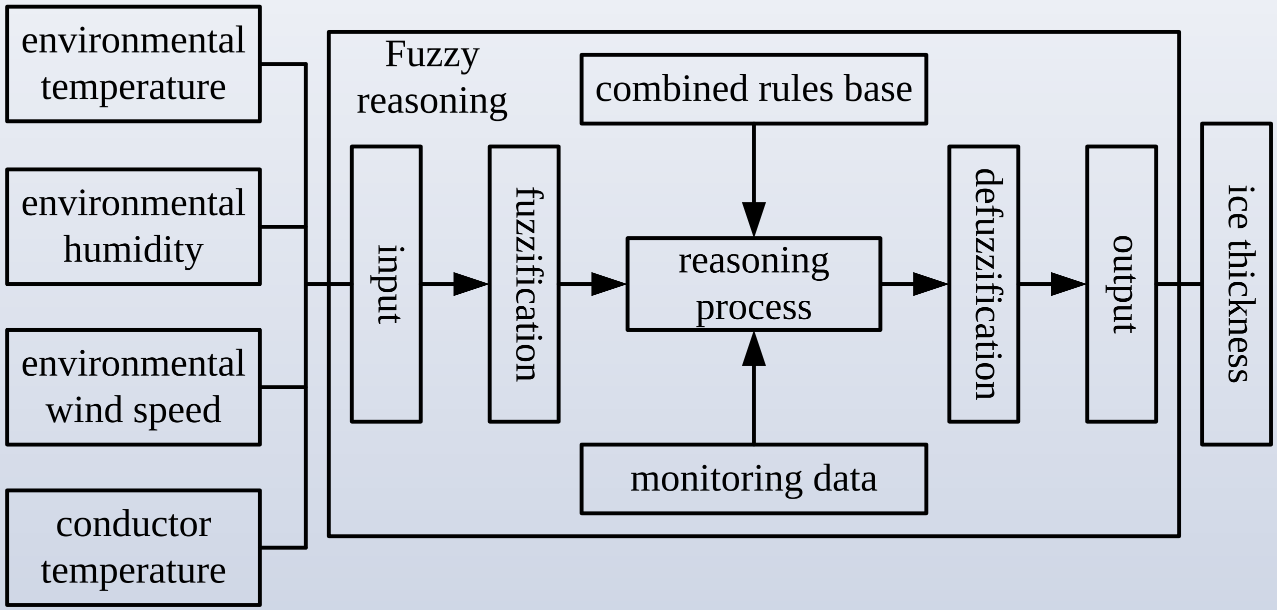
$$D(Rule2) = m_{P1}(x_1)\ m_O(x_2)\ m_{P1}(y) = 0.6\times 1\times 0.7=0.42 \quad (4)$$

Combine generated fuzzy rules and expertise experience fuzzy rules, and then set up combined fuzzy rules base.

Table 1: Combined fuzzy rules base

No.	ET	EH	EW	CT	IT	Strength	No.	ET	EH	EW	CT	IT	Strength
1	NB	NB	O	O	NS	0.8000	31	O	O	NB	NB	NS	0.8000
2	NB	NS	NB	PS	NB	0.6011	32	O	PS	NB	O	NB	0.3840
3	NB	PS	NB	NB	NS	0.8000	33	O	PS	NS	NS	NS	0.8000
4	NB	PS	NS	O	NS	0.8000	34	O	PS	NS	O	O	0.8000
5	NB	PS	O	O	O	0.4241	35	O	PS	O	O	O	0.8000
6	NB	PB	NB	NB	PB	0.8000	36	O	PB	NB	O	NB	0.2746
7	NS	NS	NS	O	NB	0.8000	37	O	PB	NB	PS	O	0.8000
8	NS	NS	PS	O	NB	0.3328	38	O	PB	NS	O	NB	0.8000
9	NS	O	NS	O	NS	0.8000	39	O	PB	NS	PS	NS	0.8000
10	NS	O	O	NS	NS	0.8000	40	O	PB	PS	O	NS	0.4569
11	NS	O	O	O	NB	0.2632	41	PS	NB	NB	PS	NS	0.5681
12	NS	O	PS	O	NB	0.8000	42	PS	NS	NB	PS	NS	0.6466
13	NS	PS	NB	NB	NS	0.8000	43	PS	NS	NS	PS	NB	0.3114
14	NS	PS	NB	O	NB	0.4167	44	PS	NS	O	PB	NB	0.2467
15	NS	PS	NB	NB	O	0.8000	45	PS	O	NB	O	NS	0.6374
16	NS	PS	NS	NB	NS	0.8000	46	PS	PS	NB	O	NB	0.4685
17	NS	PS	NS	O	O	0.8000	47	PS	PS	NB	PS	NS	0.8000
18	NS	PS	O	O	NS	0.8000	48	PS	PS	NS	PS	O	0.8000
19	NS	PB	NB	NS	PB	0.8000	49	PS	PS	O	PS	NS	0.8000
20	NS	PB	NS	NS	PS	0.8000	50	PS	PS	PB	PS	NB	0.8000
21	NS	PB	NS	O	O	0.8000	51	PS	PB	NB	O	NS	0.8000
22	NS	PB	O	NS	NB	0.8000	52	PS	PB	NS	O	NB	0.8000
23	NS	PB	O	O	PS	0.8000	53	PS	PB	O	O	O	0.8000
24	O	NB	NB	O	NB	0.4445	54	PB	NB	NB	PS	NB	0.3050
25	O	NB	NB	PS	NS	0.8000	55	PB	NB	NS	PB	NB	0.3391
26	O	NB	NB	PB	NB	0.5231	56	PB	NS	NS	PS	NB	0.1686
27	O	NB	NS	PS	NB	0.6823	57	PB	O	NS	PS	NS	0.8000
28	O	NB	O	O	NB	0.8000	58	PB	PS	NS	PB	NS	0.8000
29	O	NS	NB	PS	NB	0.4721	59	PB	PS	O	PS	NS	0.8000
30	O	NS	O	PS	NB	0.3348	60	PB	PB	O	PB	NB	0.8000

3. Establish an icing fuzzy system

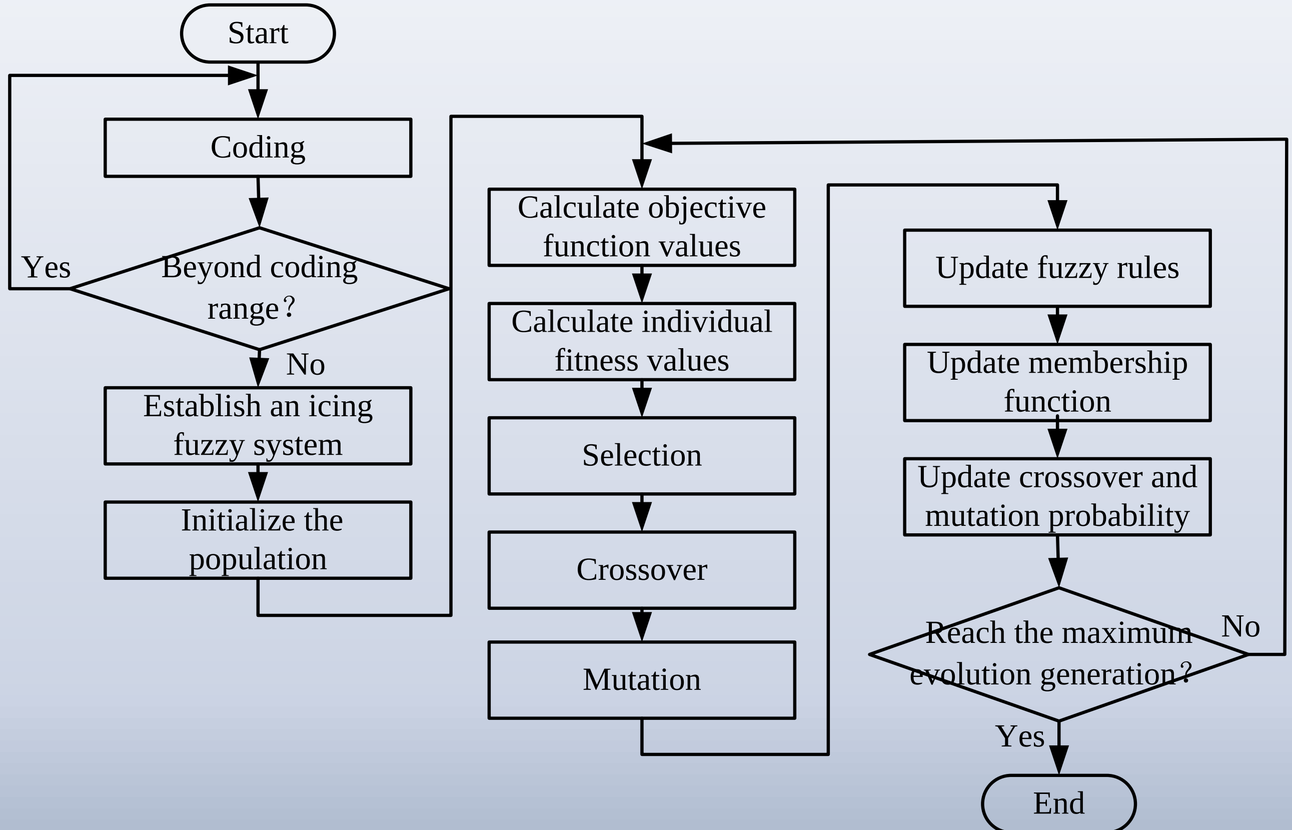


ET : -10~10℃   EH :80~100%   EW :0~10m/s

CT :-10~10℃   IT :0~30mm

Fuzzy division was five level well-distributed triangles.

4. Ice fuzzy system was optimized by using GA



Flowchart of icing fuzzy system optimized by GA

4. Ice fuzzy system was optimized by using GA

1) Initialize the population

Setting 800 as the population size, 200 as termination evolutionary generation, 0.7 and 0.001 as the crossover probability and mutation probability were respectively.

4. Ice fuzzy system was optimized by using GA

2) Coding

•Membership function coding

To ensure the increasing order of chromosome and generate invalid code string, the distance between its base end is selected as the optimization target. The width of the base of triangular membership function is defined to ensure that adjacent fuzzy partition is not isolated and has little overlap after genetic manipulation.

•Combined fuzzy rules base coding

All the elements in combined fuzzy rules base were encoded in symbols while 1 to 5 integer values correspond to five fuzzy languages N2, N1, O, P1, P2. The symbol coding is generated transforming the digitized combined fuzzy rules base to one-dimensional.

4. Ice fuzzy system was optimized by using GA

3) Improvements of genetic operation

•Improvements of selection

N chromosomes randomly selected to form a new population based on individual fitness and new populations were crossover and mutation in the population of a certain generation. In order to ensure complete population, improve population diversity, expand the search space and prevent the loss of useful gene, we calculated the fitness of each chromosome of the new population, the population operated by crossover and the population by mutation, then selected the best n chromosomes from 3n chromosomes as the next generation population. Which can ensure that the integrity of group, and improve the population diversity, expand the search space and prevent the loss of effective gene.

4. Ice fuzzy system was optimized by using GA

3) Improvements of genetic operation

•Improvements of crossover

From the perspective of the whole population, for there were large individual differences among populations in the early running GA, choose a larger crossover probability to highlight the role of crossover, thus speeding up the speed of the algorithm. At the same time choose a smaller crossover probability to reduce the likelihood of outstanding individuals destroyed in the late running algorithm because of the small individual differences.

4. Ice fuzzy system was optimized by using GA

3) Improvements of genetic operation

•Improvements of mutation

Similarly, a smaller mutation probability conducive to the evolution of population in the initial period of running. A greater probability could enhance the diversity of the population and avoid algorithm catching in local optimum in the late running algorithm.

4. Ice fuzzy system was optimized by using GA

4) Objective function

Using the minimum value of the sum of the difference between fuzzy system output values of ice and ice monitoring data as objective function:

$$J = \sum_{i=1}^{N} \left| Y_{fuzzy} - Y_{data} \right|$$

Y_{fuzzy} was ice thickness of ice fuzzy system's output, Y_{data} was monitoring data of icing, N was the number of monitoring data.

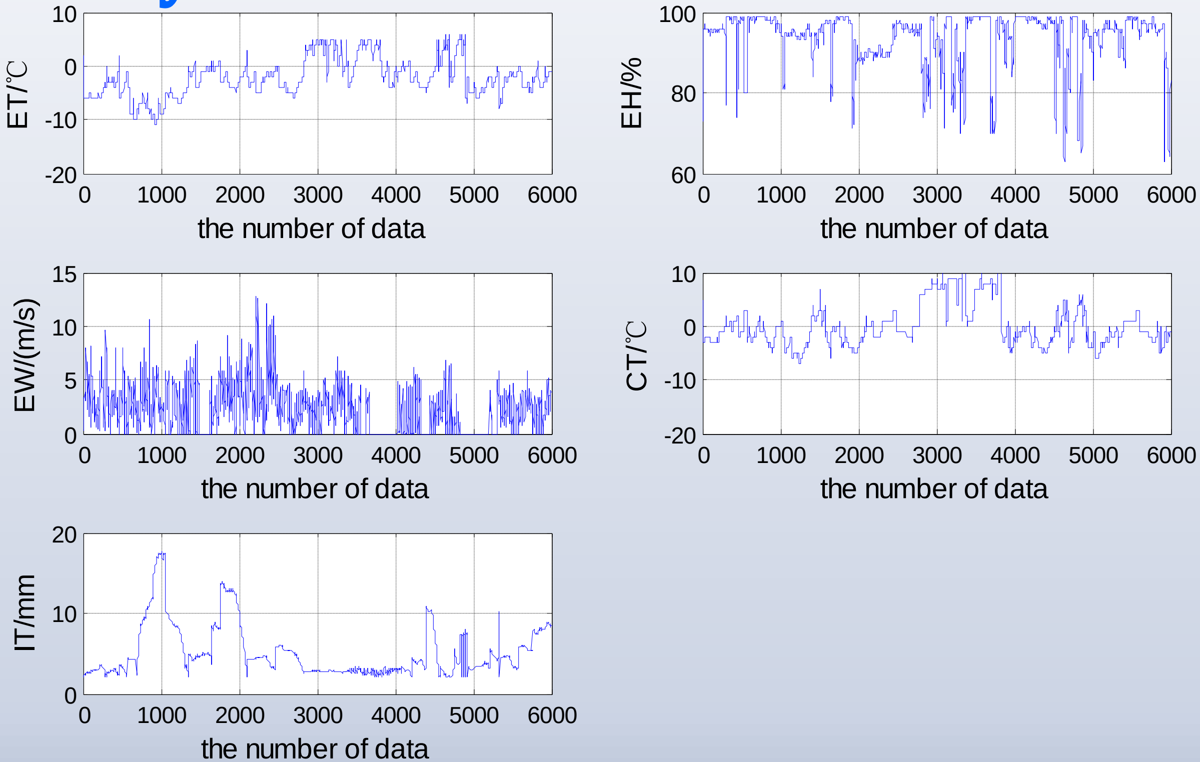
4. Ice fuzzy system was optimized by using GA

5) Individual fitness value

$$\mathrm{Fit}(y) = \begin{cases} \mathrm{Cmax} - \mathrm{J} & , \mathrm{J} < Cmax \\ 0 & , \text{other} \end{cases}$$

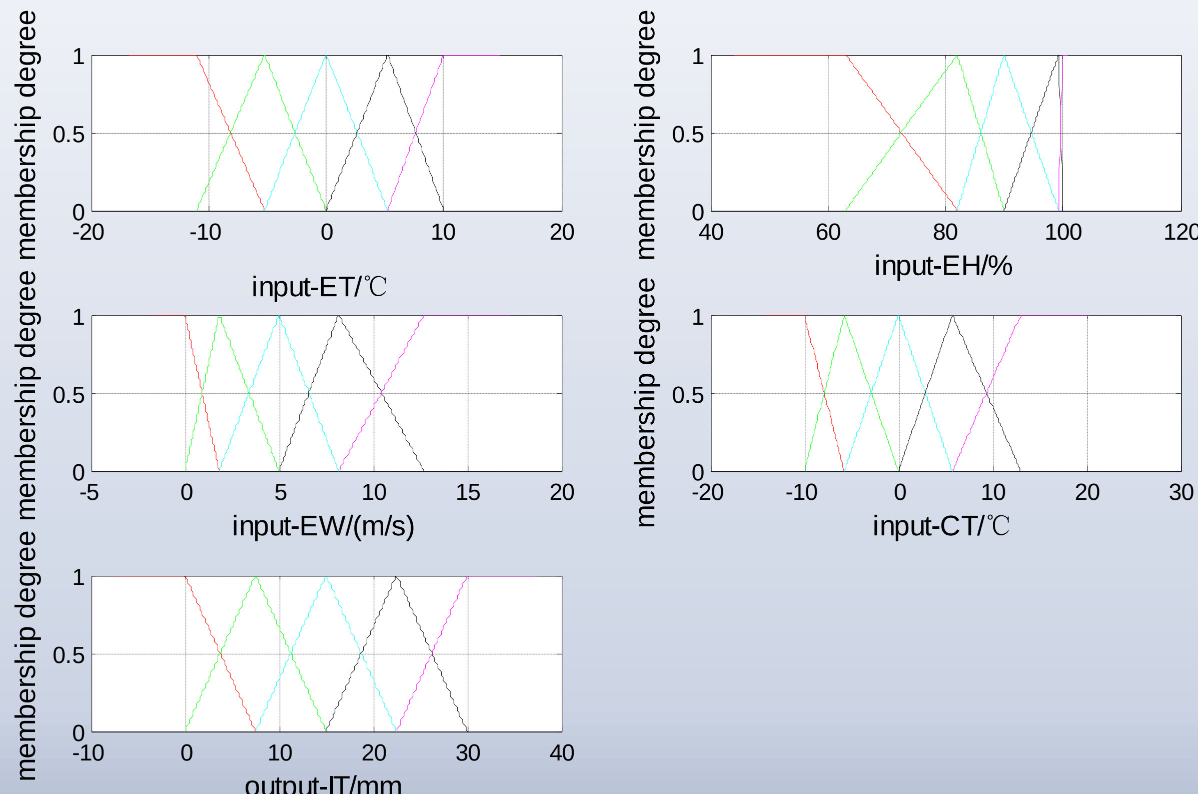
Cmax was the maximum individual fitness value in population.

5. Case study



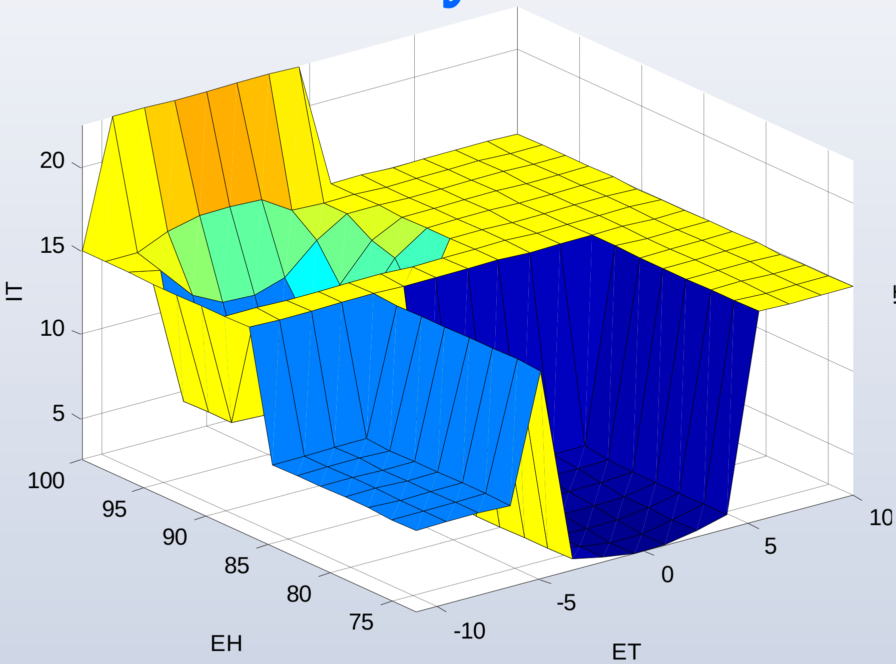
Monitoring data acquired from transmission line online monitoring system on Guizhou Power Grid in 2014

5. Case study

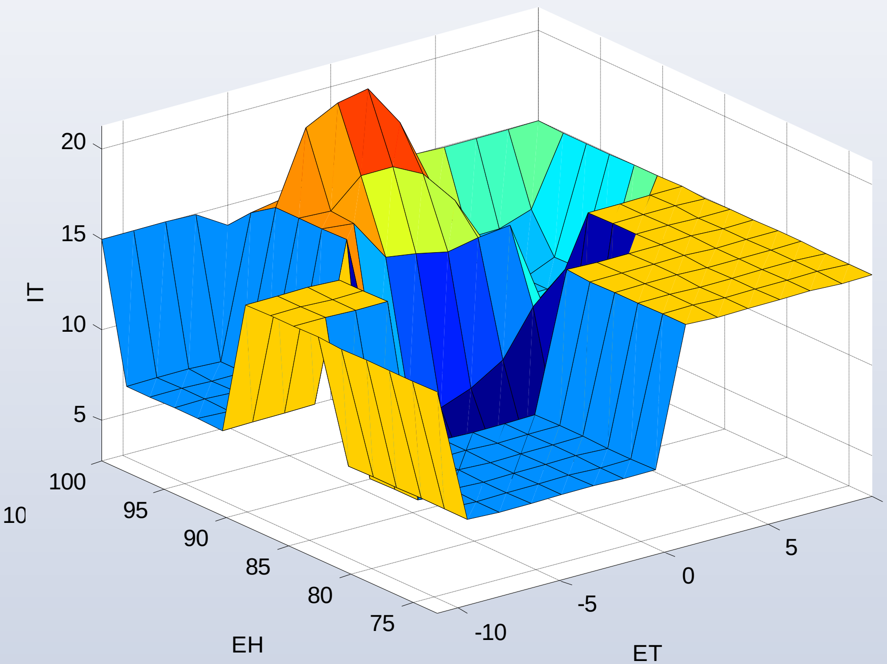


Membership function of icing fuzzy system optimized by GA

5. Case study

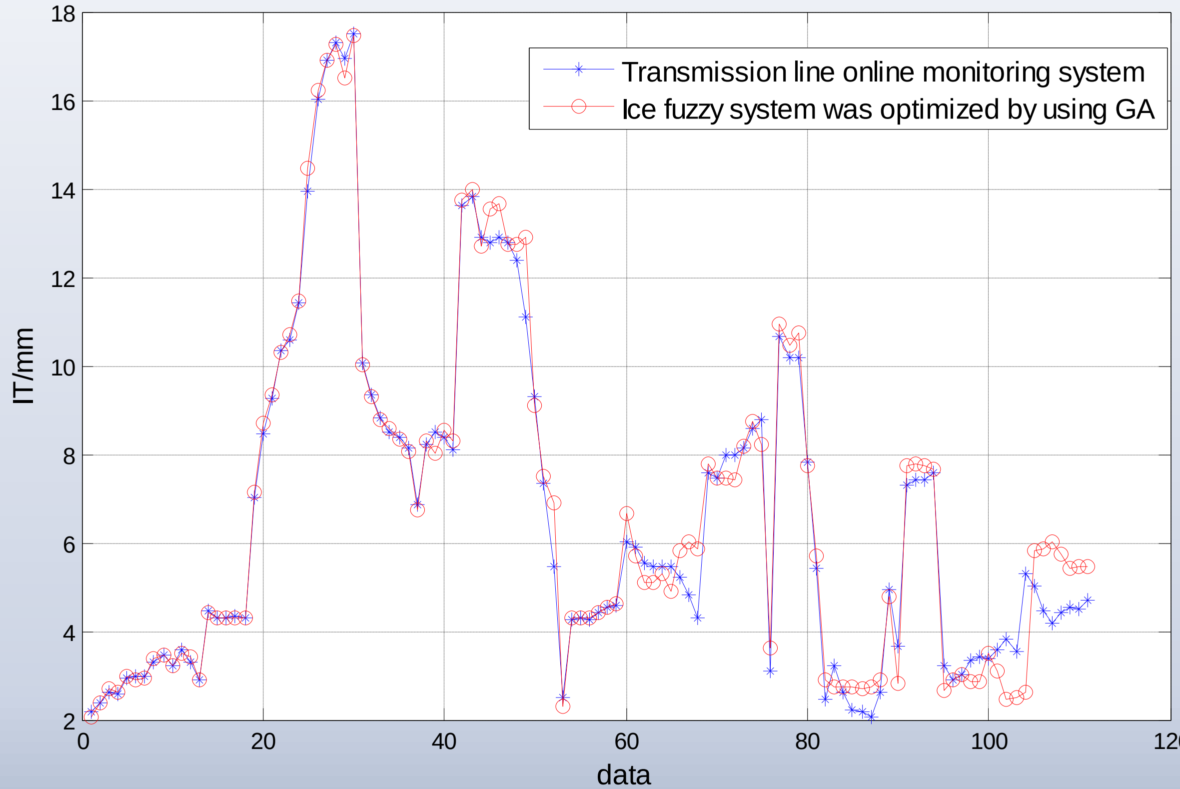


Output surface of icing fuzzy system



Output surface of icing fuzzy system optimized by GA

5. Case study



Forecasting effect of icing fuzzy system optimized by GA

6. Conclusion

ice prediction model which based on genetic algorithm and fuzzy logic fusion is established, which had the following advantages:

(1)having self-study habits, which can automatically generate fuzzy rules according to on-line monitoring data, and monitoring also had the applicability for unknown;

(2) having the self-adaptability, which can be adjusted automatically by the GA ice fuzzy system parameters;

(3)having higher prediction accuracy for line ice, which had a certain practical significance.

The Numerical Analysis for Jump Height of Multi-two-spans Ice-shedding at Different Time Intervals of Overhead Transmission Line

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Abstract

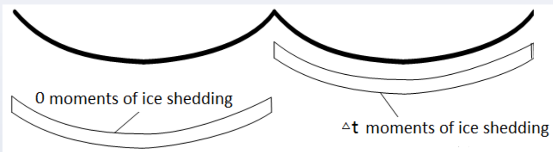
Transmission line ice-shedding is the typical fault inducement. The decreasing of the electric clearance and increasing of the dynamic tension are usually caused by ice-shedding vibration of overhead transmission line. Flashover, fittings damaged, or even wire breakage and tower collapses may be occurred if the ice-shedding vibration is serious which pose a threat to the safe operation of power equipment.

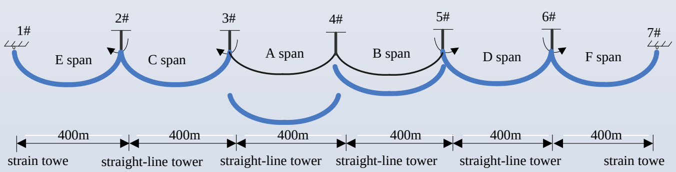
Abstract

According to different parameters of transmission line such as spans, span length, ice thickness, a finite element analysis model of wire-insulator was established, and the simulation of ice-shedding from overhead transmission line was adopted by additional force method. Then, the jump height of multi-two-spans at different time intervals can be got.

Abstract

The result shows that the amplitude of jump height decreased when the same time of ice-shedding on multi-two-spans which effect was equivalent to unilateral strain tower. The amplitude of previous ice-shedding spans is easily exceeded by the later spans when the vibration cycle of multi-two-spans interval was about 5/8. Besides, it was great impact on spans coupling such as the weight of the ice, spans, span length, damp and other factors. When the mass of the ice and spans is larger, the jump height of previous ice-shedding spans can easily passed by the later spans, but the effect of damp, span length is just the opposite.





1 | 3
2 |

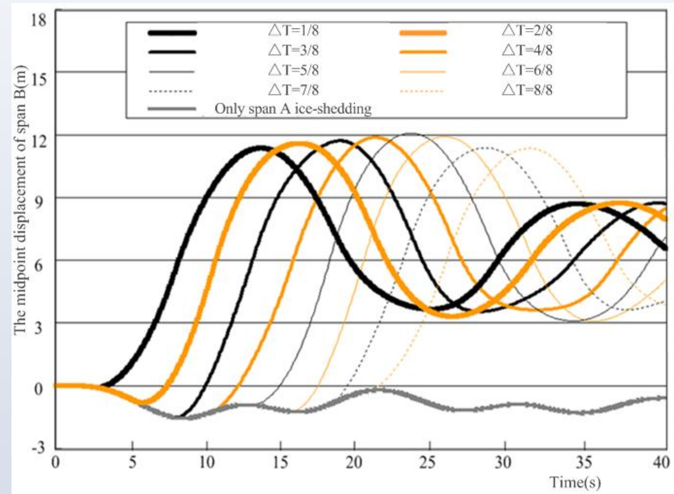


Figure 1: The way at different intervals times for adjacent two-span ice-shedding on overhead line

Figure 2: Transmission line with 7 tower and 6 span

Figure 3: Time history of displacement responses at midpoints of span B for two-span assembling ice-shedding

Influence Analysis of Transmission Lines Insulator on the Conductor Ice-shedding

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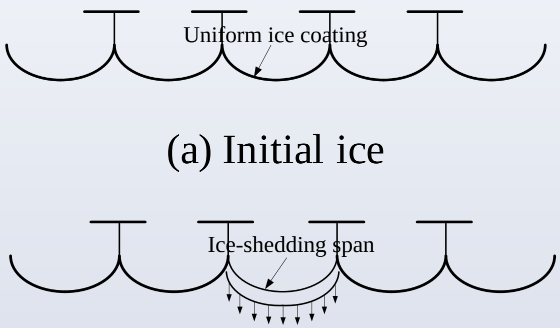
Abstract

Conductor strenuous exercise will be caused by the ice-shedding. It is easy to cause the occurrence of electrical or mechanical accident of transmission line. Therefore, Conductor-insulator finite element model has been established through the ANSYS, and it is the analysis of the dynamic characteristics for the wire type, material properties and the length of the insulator string under different ice shedding. The influence of insulator has been separately analyzed from the jump height, unbalanced tension etc. for the conductor ice-shedding. The results showed that: It I type insulator on ice-shedding unbalanced tension impact is about 0.9 times smaller than the V type insulator. It is not significant for ice-shedding unbalanced tension effects about the composite and ceramics materials. The ice-shedding jump height will be unchanged for the V type or I type insulator with the length increase of insulator string, but ice-shedding unbalanced tension will be decreased. The related results provide a reference for the subsequent study on conductor ice-shedding and lines structure design.



（b）Middle Span Uniform Ice-shedding

Figure1

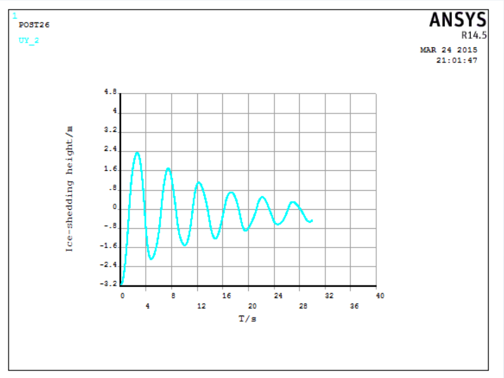


Figure2

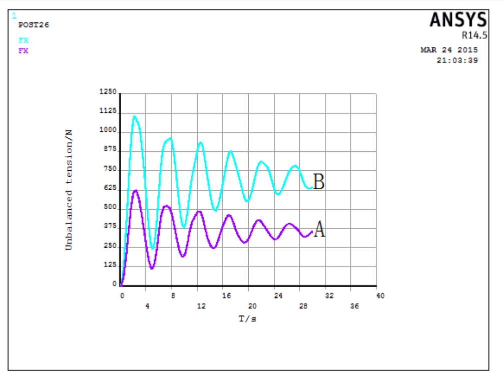


Figure3

Figure 1: Ice-shedding Span Location of Conductors

Figure 2: The jumping height of ice-shedding time-history curve

Figure 3: The longitudinal unbalanced tension time-history curve

The Recognition and Detection Technology of Ice-covered Insulators under Complex Environment

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Abstract

In order to avoid the impacts of outer factors on the ice-covered insulators recognition, such as weather, seasons, outside illumination changes, acquisition time, image background and image contrast, a general algorithm which can recognize and detect the ice-covered insulator accurately in a complex environment is put forward in this paper. With the video monitoring device, the image information of insulators with or without covered ice can be acquired. The ice-covered insulator images under complex environment are regarded as the research objects.

Abstract

Morphological closing operation is conducted on the ice-covered insulator images firstly. Then the high frequencies in the image are removed by the Wavelet Domain. A kind of invariant background quotient image can be acquired by dividing the processed images and the original images, then after the camera calibration on the quotient images, the edge contours of insulators can be extracted using the wavelet edge detection method, and the icing thickness of insulator can be obtained by using template matching algorithm and geometric model.

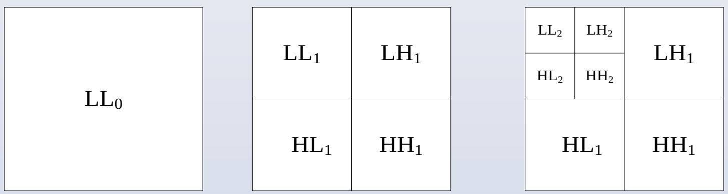
Abstract

The method is verified in an artificial climate chamber, the results show that this method can eliminate the interference of the complex background weather, accurately identify icing insulators and calculate the insulator icing thickness. This method can be applied to recognition and detection of ice-covered insulators under complex environment.

(1a) (1b) (1c)

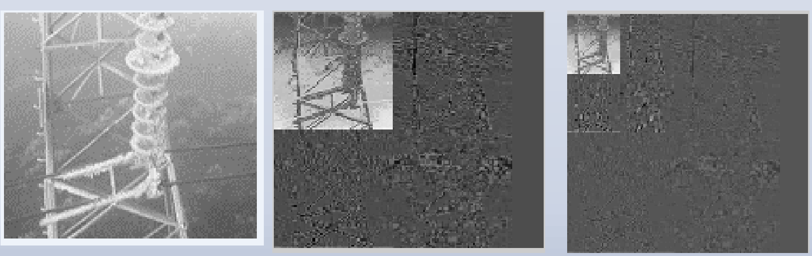
(1a) Fog day
(1b) Cloudy day
(1c) Sunny day

Figure 1: The original color image



(2a) (2b) (2c)

(2a) Original image
(2b) A decomposition
(2c) Two decomposition



(2d) (2e) (2f)

(2d) Original greyscale image
(2e) A decomposition image
(2f) Two decomposition image

Fig.2: Wavelet transfor decomposition

(3a) (3b) (3c)

(3a)Fog day quotient image
(3b)Cloudy day quotient image
(3c)Sunny day quotient image

Fig 3: Image processing effects

In indoor condition, by simulating the insulator at a humidity of 80%RH and a temperature of -19.4℉ under sunny day.

(4a) (4b) (4c)

(4a) No iced insulator
(4b) Iced Insulator
(4c) Ice thickness recognition

Fig.4: Recognition of insulator on sunny day

Thank you for your attention!