Cable deicing device based on ice melting and mechanical ice breaking

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Abstract. In recent years, it is not uncommon for high-voltage cables to freeze and break due to extreme weather, which has a great impact on power transmission and caused countless economic losses. At present, the de-icing methods on the market all have certain limitations. Therefore, this paper designs a de-icing device that uses thermal ice melting and mechanical ice breaking at the same time, which can reduce the difficulty of ice breaking and damage to cables by heating ice layers, and spray special coatings to prevent icing again after ice breaking. This device has higher adaptability to cable de-icing and can better meet the needs of de-icing.

1. Project background and research significance

1.1. Project background
High-voltage cable is a kind of power cable, which is used to transmit power cables between 1 kV and 1000 kV, and is mostly used for power transmission and distribution. Protecting the normal operation of high-voltage cables is a necessary measure to ensure the normal production and life. At present, the hidden danger that affects the normal operation of high-voltage cables is icing in extreme weather, which is difficult to remove, and severe cases may lead to cable breakage. In recent years, the frequency and intensity of meteorological disasters caused by extreme weather and climate events are increasing. Taking January to February, 2017 as an example, most areas in China, especially the southern region, were hit by low temperature, rain, snow and freezing weather for four consecutive times, which caused more than 100 million people to be affected, and the direct economic loss exceeded 150 billion yuan, especially for the power sector. The icing thickness reached 40-50mm, which had a disastrous impact on the operation of power equipment.

Figure 1. Cable broken due to icing.
The existing treatment methods are artificial deicing and device deicing, but there are some problems, such as high risk, low removal efficiency, easy secondary icing, easy cable damage, etc. At present, a new type of cleaning device is urgently needed to remove the icing of high-voltage cables to ensure the safety of production and life. As shown in Table 1, the comparison of main cleaning methods at present is listed.

### Table 1. Comparison table of three de-icing methods.

| Deicing mode       | Advantages                           | Disadvantage                                      |
|--------------------|--------------------------------------|---------------------------------------------------|
| Artificial deicing | The fixed-point cleaning effect is good | Low efficiency and potential personal safety hazards |
| Short-circuit      | Large cleaning area and high efficiency | The scope of application is narrow, which has an impact on the lives of residents |
| current deicing    | Easy to operate and simple to use     | The cleaning method is single and the cleaning effect is poor |
| Robot deicing      | Simple operation and long action time | The cleaning effect is random                      |
| Installing deicing ring |                                  |                                                   |

1.2. Research significance

Based on the above background, we designed a hot melt and mechanical cleaning method, and assisted the application of waterproof coating. This method can not only achieve higher efficiency, but also save a certain amount of energy loss, and also prevent secondary icing, which improves the cleaning efficiency of ice layer. It has the following advantages:

(1) The ice layer is cleaned by hot melting and mechanical means, which saves energy consumption and ensures cleaning efficiency and cleaning effect.

(2) The device adopts two ways to melt the hard ice layer, and mechanical removal ensures the cleaning effect and improves the working efficiency, and the application of waterproof coating can prevent secondary icing.

(3) The device is small and can work stably when working in the air.

The design of this device realizes the problem that the icing of high-altitude cable cannot be cleaned in time, and realizes intelligence and automation. It is suitable for deicing high-altitude cable which is inconvenient for manual cleaning.

2. Research contents and objectives of the project

2.1. Research content

(1) Determine the location and characteristics of the ice layer of high-altitude cable, understand the current deicing mode of high-altitude cable, and determine the appropriate and efficient deicing mode;

(2) It is necessary to design the walking structure inside the device, and how the mechanical deicing module works to make the device work normally and continuously and efficiently, and consider whether the device will be blocked and how to solve it;

(3) According to the overall work of the device, the structure design of the shell is carried out, and the scheme is determined so that the device can reduce the volume of the device and realize the most stable shape;

(4) Investigate the waterproof coating to determine which waterproof coating has the best effect;

2.2. Research objectives

(1) The device can remove the ice layer of cable by combining hot melting with machinery, and the waterproof coating can effectively prevent secondary icing;

(2) The stable movement of the device is realized by designing the internal structure of the device;

(3) Through the design of the structure, the device can realize the corresponding functions stably and efficiently.
3. Project objectives: The implementation scheme of research and the research methods and technical routes to be adopted

3.1. Overall scheme
The device is mainly composed of a hot melting module, a front fixing module, a space scissor movement module, an ice breaking wheel module and a sensor module. When the device is used, it needs to be opened manually and the cable is wrapped inside the device. The device uses the principles of hot melting and mechanical method to blow hot air from the cross-sectional direction of ice, and at the same time, the ice is peeled off by the movement of the ice wheel, so as to remove the ice attached to the high-altitude cable. In addition, in order to prevent the negative impact of secondary icing on cleaning, the cable will be dried inside the device, and after the treatment, the cable will be coated with waterproof coating for the first time, so that precipitation or snowfall cannot adhere to the cable as a carrier to form ice crystals. The movement of the device is fixed by the lock catch, and the bionic movement mode is adopted, which is convenient for the flexible replacement of the device. The device diagram is shown in Figure 2, and its working flow chart is shown in Figure 3 below.

![Overall drawing of device](image1)

1. Hot melt module; 2. Pre-fixed module; 3. Spatial scissor movement module; 4. Ice-breaking wheel module; 5. Maintain the coating module.

**Figure 2.** Overall drawing of device

![Overall work flow chart](image2)

**Figure 3.** Overall work flow chart.
3.2. Research methods and technical routes

3.2.1. Ice melting module. The module uses the hot melting method, which melts the ice layer on the cable surface mainly by heating the electric heating wire, and at the same time plays the role of peeling off the ice on the cable surface with the pressure of the ice-breaking wheel. STM32 controller is used in the working control part of the heating wire. According to the investigation, the working of the cable will be greatly affected when the thickness of the ice layer on the cable surface is 10 mm. Based on this, we control the temperature of the heating wire through the controller. According to the investigation, the tolerable temperature of the outer insulation of the cable is -35~+100°C. Therefore, we set the temperature of the heating wire at 40°C, which can not only melt the ice layer, but also achieve better results with the follow-up treatment.

3.2.2. Drying module. As the pre-treatment only melts ice, there will still be some residual water on the surface. If it is not treated in time, it will produce secondary icing under the influence of low temperature, which will be more difficult to treat. Therefore, the drying module will be designed after the melting treatment. The drying module consists of a roller brush and a hot blowing device. After pre-treatment, the melted ice water is first treated by the brush, and then the cable is further dried by hot blowing, which is also ready for the next operation. The structural schematic diagram is shown in Figure 6.
3.2.3. **Maintenance module.** After being treated by the last drying module, in order to prevent the cable from freezing again due to the harsh environment, a super hydrophobic coating is proposed to treat the outer part of the cable once. The technology of this material is relatively mature now, and it will be cured within 15min after use, so it can be used to protect cables. The liquid material is stored in a container, transported to the surface of the rear fixed arm by a switch controlled by an electromagnetic valve, and coated on the surface of the cable by the relative movement between the device and the cable.

![Rear fixed arm](image)

**Figure 7.** Maintenance module.

3.2.4. **Sports module.** The motion module adopts the motion mode of bionic insect, which is mainly realized by scissor mechanism, and the spatial scissor mechanism can realize linkage. When the scissor mechanism in the middle is stretched under stress, the left and right arms can be clamped, so that the cable can be clamped in the center of the fixed arm. At this time, the expansion and contraction of the scissor mechanism of the left and right arms can realize the forward movement of the device. The movement of the device is controlled by STM32 with the help of remote-control module CM4301PD02, wireless remote-control module 433 and remote transmission A7103. According to the data, the working temperature of this module is -10 ~+60 C, and the communication distance can reach 2km, which is suitable for the device.

![Spatial scissor mechanism](image)

**Figure 8.** Spatial scissor mechanism.

3.2.5. **Sensor module.** In order to prevent the damage caused by the bridge not changing the path in time during the automatic movement of the device, an obstacle avoidance sensor will be added to the shell. When the distance between the device and the object in front is too close, the device will stop working and automatically cut off power, and realize the alarm in the manual console. At the same time, the device is equipped with a USB camera, which can be called at any time through the control terminal, so as to monitor the cleaning effect in real time.
4. Research basis and feasibility analysis of the project

4.1. Research foundation

Based on the current research on cable deicing technology, we find that most of the existing treatment methods will cause potential safety hazards, and the most commonly used short-circuit current heating and melting ice layer method is easy to use and has good effect, but it has great potential safety hazards and will have a certain impact on the service life of the cable surface. Based on the data of related papers, the experiment was carried out, and suitable materials were selected for different modules to ensure the stability of the device. In the process of research, certain data will be obtained through experiments by controlling variables, analogy and other methods, and further research and improvement will be carried out.

4.2. Project feasibility analysis

4.2.1. Weight analysis of the device. According to the data, the insulation shell of the cable is mostly PVC, and the inner part is filled with plastic products. According to the national standard, the tensile force of the cable is not less than 140N, and the design weight of this device is 8kg, which is less than the tensile force and will not damage the operation of the cable.

4.2.2. Feasibility calculation of melting ice and breaking ice. This device mainly needs to experiment and discuss the deicing effect. This device uses hot melting method to melt. This time, we choose heating wire as the main body of the melting module. According to the data, under the condition of ensuring safety, the heating wire can melt the ice layer at 40℃.

To break ice, we use the rotating pressure of ice-breaking wheels to break ice. We take D=150mm in diameter. Each ice-breaking wheel is distributed with Z=4 ice-breaking blades. The rotating speed of ice-breaking wheels is designed as n=40r/min, so the striking force of ice-breaking teeth on ice surface can be expressed by momentum:

\[ P = m \times v \times z \] (1)

Where: \( P \)-the impact force of the ice-breaking teeth on the ice-breaking blade on the ice surface; \( m \)-the mass of a single ice-breaking tooth, taking \( m = 0.1kg \); \( v \)-the relative speed of the road surface when the ice breaking blade rotates to the contact position with the ice surface, and \( v = 6m/s \).

After calculating \( P = 0.3 \text{ kg m/s} \), the impact time is \( t=0.02s \), considering the speed of ice breaking wheel and ice condition. Therefore, the impact force given to the ice by a single ice-breaking tooth is:

\[ F = \frac{P}{t} = 15N \] (2)
And the contact area between ice-breaking teeth and ice surface is $s=0.15\text{mm}^2$, so the impact load of ice-breaking teeth on ice surface is:

$$\sigma = \frac{F}{s} = 100\text{Mpa} \quad (3)$$

The anti-impact load of ice is $[\sigma]=78\text{Mpa}$, so the ice surface can be broken.

4.2.3. Selection of power supply mode and working efficiency. The power supply of the device is provided by lithium battery, which is light in weight and can work continuously for more than one hour. Taking cables in mountainous areas as an example, the distance between cable supports is generally about $l=200\text{m}$, the moving speed of this device is $v=10\text{m/min}$, and the time required to clean a cable is $t$:

$$t = \frac{l}{v} = 20\text{min} \quad (4)$$

At present, the widely used short-circuit current melting method has low heating efficiency, generally takes more than 30min minutes, and is easy to form secondary icing. By comparison, the working efficiency of the modified device is higher than that of the current deicing method, and good deicing effect can be achieved.

5. Innovation point

(1) By combining different mechanical structures, the device can walk smoothly on the cable, and the application area can be expanded by remote control, while the waterproof coating can prevent secondary icing;

(2) The device can realize ice melting and deicing at the same time, realize work efficiency and improve deicing effect;

(3) The volume and weight of the device are changed according to the application point, which makes the use safer and more suitable for deicing high-altitude cables;

References

[1] Qi Chenyu. Structure Design of Portable Adaptive Cable Deicer [J]. China High-tech Enterprises, 2015(36):16-17.

[2] Yin shuqing, Zhao Shanshan, Wang zunya, Zhang Qiang, Tang Wei’ an. national prediction model of wire icing thickness distribution and grade [J]. journal of applied meteorological science, 2009,20(06):722-728.

[3] Dong Chunbo, Liu Siyang, Fu Tianshu. Cable deicing system design [J]. Science and Technology Innovation and Application, 2017(13):28-29.

[4] Chen Zhikang, Li Shulong, Yuan Tongsen, Zhang Dengchun. Thermodynamic simulation of deicing system of bridge heating cable [J]. hunan communication science and technology, 2016,42(01):59-64.

[5] Jiang Cong. On the research of anti-icing and deicing technology of overhead power lines at home and abroad [J]. Electronic Manufacturing, 2015(10):235.

[6] Wang Yu, Wang Mu, Su Helin. Design and application of high altitude cable drive and vibration deicing mechanism [J]. Electrical Application, 2013,32(13):90-93.