FEASIBILITY COMPARE OF REMOVING AND MELTING ICE TECHNOLOGY OF TRANSMISSION LINE

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Abstract: This submitted paper introduced many methods including heat removing and melting ice, mechanism removing and melting ice, natural passivity removing and melting ice, and so on. This article also has discussed the feasibility of removing and melting ice methods.

1. INTRODUCTION

In order to reduce the adverse effects of snow disasters for transmission lines, Varying degrees technology research of removing (melting) ice have been Carried out at home and abroad. At present, the technologies of deicing applied and being developed are more than 40 kinds. In accordance with the principles, It can be divided into heat removing and melting ice, mechanism removing and melting ice, natural passivity removing and melting ice and other methods, these methods have some shortcomings of themselves, The evaluation of feasibility should take into account various factors, such as: the level of applied to overhead lines、 energy consumption of themselves、 effects of removing ice production cost、the input-output price ratio of practical application and the actual operation ,etc

2. FUNDAMENTAL PARTITION

2.1 Heat removing and melting ice

(1) AC current melting ice (see Table 1)

Table 1: Calculation Result of AC Short-Circuit De-icing.

Voltage of Power System /kV	100 km		150 km		200 km	
	Short-circuit /A	Capacity /MVA	Short-circuit /A	Capacity /MVA	Short-circuit /A	Capacity /MVA
35	722	44	481	29	361	22
110	2268	432	1512	288	1134	216
220	4536	1729	3024	1152	2268	864
500	10310	8929	6873	5953	5155	4465

(2) DC current ice-melting

2.2 Mechanical ice- removing

(1) “ad hoc” method

(2) Pulley rolling chipped method

(3) Strong vibration method

(4) Electro-Impulse Deicing

(5) High frequency high voltage excitation deicing method

(6) New robot deicing

2.3 Natural passivity removing and melting ice

2.4 Other methods

(1) CO2 laser l melting method

(2) Magnetic material wire with low Curie point

3. CONCLUSION

In the deicing methods, despite the fact that there exist a lot of technical methods, but most of them are still in the experimental stage or only applied to key lines, so further research for the large-scale deicing for transmission lines should be proposed to prevent and solve the similar practical problems caused by extreme climate.

Based on the analysis of various deicing methods, it is concluded that heat removing and melting ice method is effective , and its cost is high; mechanism removing and melting ice method consumes less energy, its cost is low, and it is strongly passive and with too much work, and also restricted by the geographic condition; the natural passivity removing and melting ice method is easy but the result is not so good; other ways are restricted by various conditions and are unable to put into practice. Compare to other methods, heat removing and melting ice method is the most sophisticated, currently, the specific method already used mainly includes over-current ,melting ice method, AC short-circuit current melting ice method, direct current melting ice method, etc. For the transmission line of 500KV or higher voltage, because it is difficult to find the appropriate power source, so AC short-circuit current melting ice method cannot be adopted, but only the direct current melting ice method.

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Keywords-heat removing and melting ice, mechanism removing and melting ice, natural passivity removing and melting ice

I. INTRODUCTION

In order to reduce the adverse effects of snow disasters for transmission lines, Varying degrees technology research of removing (melting) ice have been Carried out at home and abroad. At present, the technologies of deicing applied and being developed are more than 40 kinds. In accordance with the principles, It can be divided into heat removing and melting ice, mechanism removing and melting ice, natural passivity removing and melting ice and other methods, these methods have some shortcomings of themselves, The evaluation of feasibility should take into account various factors, such as: the level of applied to overhead lines、energy consumption of themselves、effects of removing ice production cost、the input-output price ratio of practical application and the actual operation, etc.

II. HEAT REMOVING AND MELTING ICE

Heat removing and melting ice is recognized worldwide as the most effective de-icing technology, it uses principles of melting ice by Joule effect and warms the wires to clear up the ice.

A. AC Current Melting Ice

This method keeps the normal operation of lines and increases the current of line, increasing the line heating, in order to achieve the purpose of melting ice , mainly in the following categories:

(1) Load transfer, namely change the current distribution by scheduling

This method doesn't need to increase any equipment, it mainly relies on scientific scheduling, changes the current distribution, uses the thermal effect of the load current to make the line current reach the critical current of melting ice. Because in the normal operating mode it may bring lots of inconvenience to transfer the current, and it is difficult to control the needs of users. Therefore, the risk of failure melting ice is very high, it may also cause system instability, and the trend of current transfer is limited.

This method is suitable for single split wire, for the division lead, due to the required large current of melting ice and possible impact on grid stability, the method does not apply.

(2) ONDI

It was proposed to melt ice with load in 1990, and developed at a later. This method changes the angle of phase-shifting transformer to change the parallel transmission lines' current distribution, it increases the one loop's current to increase the line fever to achieve the goal of melting ice.

ONDI needs to install the phase-shifting transformer. During the operation it may increases the amount of reactive power transfer, and causes impact on system security and stability. For multi-split wire line current can be concentrated in a split wire to increase the heat. By changing the line we can melt the ice of wire. This method requires the insulation of the split wire, and needs to conduct large-scale transformation on the line.

(3) Melting ice by short circuit

It is that we make the end come into being two-phase or three-phase short circuit when the other end operate normally to become short-circuit current .It will heat the wire to melt ice.

This method only for 220kV and below voltage lines is feasible, for 500kV and above voltage lines it will not work. Because 500kV lines mainly adopt the large section and multi split wire ,it needs large current of melting ice, for 4×300 model, the current minimum of melting ice is about 2500A, for 4×400 model ,about 3000A.From the table 1, we can see that when 35kV and 110kV are used as power source of melting ice, the short-circuit current of 500kV line can’t meet current minimum of melting ice. When 220kV is used as power source of melting ice, the short-circuit current can reach the required current of melting ice, but the line length must be within a certain distance. For example, the line of 4×400, length can’t exceed 150km, and the reactive power capacity provided by system requires more than 1GVA,the system may not meet the demands. When 500kV is used as power source of melting ice, the short-circuit current can reach the required current of melting ice, but the larger reactive power (2GVA more), at the same time we must also consider whether to maintain stable operation of the system. Therefore, for 500 kV or higher voltage

transmission lines, because it is hard to find power to meet the requirements of the melting ice, AC current melting ice is not feasible.

Table 2. Calculation Result of AC Short-Circuit De-icing.

Voltage of Power System /kV	100 km		150 km		200 km	
	Short-circuit /A	Capacity /MVA	Short-circuit /A	Capacity /MVA	Short-circuit /A	Capacity /MVA
35	722	44	481	29	361	22
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note :When calculating the system impedance ignored

When we adopt three phase short circuit to melt ice, we need to stop all overhead power lines including the lines of melting ice among all ice-melting loops, the power source of melting ice is usually provided by the system. So it is the only way to adopt the way of impact closing, when the system voltage is low and the reactive power reserve is not enough, it may do harm to the stability of system .It needs to retrofit the switch in short-circuit side into the existing power grid (normally open) to achieve the three-phase short circuit. Isolation switch in the power supply side and overhead lines or cables should been installed to achieve the connections of the power source and the lines of melting ice, so a lot of work preparation needs to do. The power need by the three phase short circuit to melt ice is very impressive, more often than tens of thousands of kWh. AC current melting ice may cause a serious impact on operation mode of grid, stopping and restoring the power is complex, and the operation time is very long.

B. DC Current Ice-melting

DC ice-melting is a new and sufficient method about ice-melting of transmission lines, which has overcome technological limitations and shortcomings of AC melting mode, it has some following characteristics.

One is that the inductive component of line impedance is ineffective, it decreases the power of DC ice-melting and improves the efficiency a lot.

The second is the adjustable voltage which can meet the demands of various lengths of lines without impedance matching by adjusting the voltage of DC ice-melting.

Third, the DC deicer of the base station could work on all incoming and outgoing transmission lines sharing one set of device. It has an obviously effect especially on the large scale ice coating lines. The displaceable DC deicer could work on the melting ice aiming at partial ice coating lines.

The DC deicer has limited using time and great maintenance difficulties because of its heavy investment used for ice deicing. In order to improve the efficiency and availability of DC deicers, a DC transmission converter station, which used for power transmission under normal conditions and a deicer when coating in winter, or used as a STATCOM at ordinary times, could be built on heavily icing region. A STATCOM amounts to a three-phase source with adjustable voltage amplitude and phase, could compensate not only reactive power but also reactive power instantaneously, with good dynamic performance.

On October 2008, the first 60MW base station DC deicer of the world achieved success in Fuquan 500kV-Substation at Duyun, Guizhou Province. This symbolized that DC deicer of Southern Power Grid has been up to the world's leading level in researching and installation. On August 14th, 2008 and September 5th, a 500kW removable generator and a 25MW station device have been installed and debugging completed at Tongren and Duyun Power Supply Bureau of Guizhou Province.

III. MECHANICAL ICE-REMOVING

Mechanical ice- removing method uses a variety of mechanical power which produces stress to destroy the internal structure of the ice, so that the ice could break away from the surface of ground line.

A. "Ad Hoc" Method

The method applied currently is external strike, which called "ad hoc" aboard. It was proposed by Phlman and Landers in 1982, needing to operate on the spot, and it has various processes as well, including striking, hitting and so on. The manual ice removing is available when the line is powered off, using methods such as removing ice by throwing short sticks against the wire and arrester from ground, or hitting with sticks if the ice can be touched. When the line is charged, an insulating rod with the right voltage level should be used to hit the wire, and a helicopter or shotgun can be used as well. In addition, pulling down a wire with a wooden ring can also make it.

"Ad hoc" is simple and convenient for deicing, but its small range of application, ore effective methods.

B. Pulley Rolling Chipped Method

By Canada Manitoba following developed pulley chipped technology is a kind of ground operation personnel by pulling pulley online to walk and eradicate wire cladding ice, pulley rolling chipped in Manitoba, Canada has used for over 50 years, it is currently the only feasible transmission lines removing ice mechanical method. It consists of pulley, drawing rope and painting plywood or epoxy resin plate, etc. The force added in the pulley should be enough to let wire bended, the stresses can make ice broken off. If there is a serrated knife on both sides of the board, then the effect of removing ice is better, but when pulling we should pay more attention to do not damage to the wire, lightning wire and insulator.

The biggest advantage of pulley chipped method is easy to operate, has effect soon, consumes little energy consumption, is low prices, and is relatively practical. But it also has shortcomings, those are time-consuming, safety performance is not perfect, and by topography restrictions. According to statistics, one kilometer long wires need about 1-2 hours.

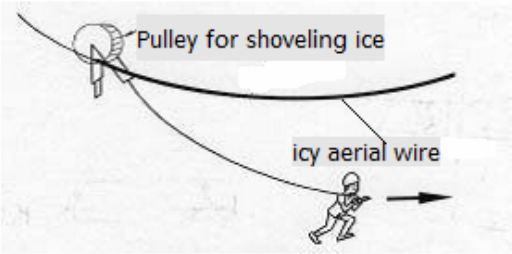

Figure 3. schematic of Pulley rolling chipped method

C. *Strong Vibration Method*

The strong vibration method was developed by Mulherin and Donaldson in 1988. The water power substation in Quebec, Canada invented a cable deicing device which included a pair of wire. The wire is connected to the cable and spiral wound along the cable, one end of the wire is connected to a device which can generate electromagnetic pulse travelling along the cable, the other end is connected together to form closed circuits. The electromagnetic pulse travels along the circuit to generate impulsion which can cause the cable vibrate and thus make the ice break off.

This method requires external vibration source and leads to cable fatigue, making it difficult to put in practice

D. *Electro-impulse Deicing*

The basic principle of the Electro-Impulse Deicing method (EIDI for short) is like this: a coil is charged by a capacitor to generate high magnetic field, thus to generate a strong short-duration mechanical force in the vicinity of the coil to break off the ice. This method has successful deicing experience applied to airplane.

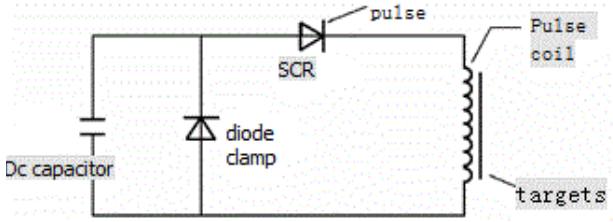

Figure 4. schematic of electrical impulse deicing method

EIDI is effective to some degree for glazed frost, its effect is limited for glazed rain, but it is ineffective for deicing. And experiment result shows that this method is only effective to short line(3～5m); When the line is long enough, although the impulse vibration can travel to the middle of the line along the line but it is unable to break off the ice. Increasing the voltage can improve its deicing ability greatly, but the line will shake intensely.

Because EIDI cannot remove the ice covering a long line, so it is hard to put it into practice.

E. *High Frequency High Voltage Excitation Deicing Method*

Under high frequency, ice is a lossy dielectric and can generate heat; moreover, the skin effect makes the current to travel along the shadow surface, thus more heat loss is greater as there is more resistance.

When high frequency source is applied to the transmission line, there will be standing wave along the line. The dielectric loss heat effect and resistance heat effect caused by skin effect for ice are both not uniform. At the wave loop of the voltage wave, the dielectric loss heat effect is strongest and at the wave loop of the current wave, the heat effect caused by skin effect is strongest, if they can complement with each other in the appropriate proportion, the combined heat effect for the whole line will be uniform. The recommended frequency for deicing is 20～150 kHz.

However, due to the high frequency electromagnetic interference, this method is restricted in many countries. Currently, the deicing device based on this method has been tested on a one meter line, and the deicing effect is significantly, but it cannot be widely used as a mature technology.

F. *New Robot Deicing*

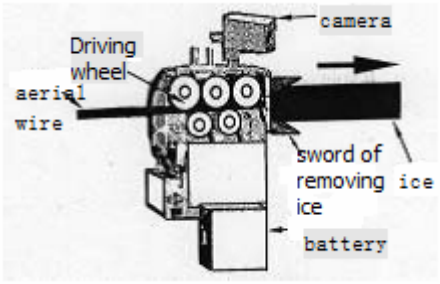

Figure 5. Schematic diagram of electrical machinery deicing equipment and its actual working drawings

The Hydropower Research Institute at Quebec, Canada, developed an electrical machinery deicing device which can remove the ice on the high voltage transmission line and the overhead line, see Figure 5.The main body of the device is a movable rack with power source, and at the front part of the moving direction there is a deicing blade rotating in a high speed and moving around the line, it can cut up the ice and snow. The disadvantage of the device is that it cannot pass the accessories on the split line, such as electric power fittings and FFJQ.

IV. NATURAL PASSIVITY REMOVING AND MELTING ICE

The passive deicing method is to install some devices, such as snow basket, balance weight, on the line to make it

difficult for the snows to get together on the line, it requires no external energy, only rely on wind, gravity, random scattering, temperature changes and other natural forces to remove the ice. Although this method requires no basic costs and the operation cost is not so much, it is inefficient, restricted by natural conditions and can only apply to certain type of ice, so the reliability of the method is not guaranteed, currently it is still expedient. So generally by installing certain device (e.g. balance weight, deicing ring), it can leads to effective efficient passive deicing. For example, Electricity De France and Nanyang electric power bureau in Henan province had used weight-balancing anti-ice ball and got good results. Japanese power companies also researched into the deicing mechanism of anti-ice ring in depth and did experiments, they concluded that the combination application of rings at regular intervals and anti-ice balls can get good results

V. OTHER METHODS

A. CO_2 Laserl Melting Method

The penetrating length of CO_2 laser in ice is short and ice can absorb it effectively. CO_2 laser l melting method and deicing based on its own gravity are working collaboratively.

First, CO_2 laser melts the ice on the interface between the device and the ice, the melted water constantly flows on the interface causing the melting of the adhesion part of the ice to reduce the adhesive force on the surface of the device. Under the influence of the gravity of the ice and slight shake, the whole ice is likely to fall off.

Researchers in Huazhong University of Science and Technology used 35W CO_2 laser to shot the interface of the ice and the insulator to reduce the adhesive force to remove the ice in whole, and it was measured that to remove 1 kg ice, 90kJ energy and 26 minutes were needed.

At present, there is no actual application of this method.

B. Magnetic Material Wire With Low Curie Point

In early 70s last century, researchers in United Kingdom first use materials with low Curie point as deicing sleeve, and the results were not so good. In the late 80s, researchers in Japan developed magnetic material wire with low Curie point, and twined it around the transmission line covered with ice, and got good results.

When the temperature is above the Curie point, the low Curie material shows no magnetism; when the temperature is below the Curie point, its magnetism is strong, and the loss is increased, thus more heat is generated.

This material was used in the 110kV-500kV lines in 1990 and 1992, the effect is promising. The heating value of developed magnetic wire is 26W/kg when the temperature is 0°C, but when the temperature is 20°C, there is still 5W/kg heat loss.

Because the cost for magnetic material wire with low Curie point is high, at present, there is no wide application in China and also aboard.

VI. CONCLUSION

In the deicing methods, despite the fact that there exist a lot of technical methods, but most of them are still in the experimental stage or only applied to key lines, so further research for the large-scale deicing for transmission lines should be proposed to prevent and solve the similar practical problems caused by extreme climate.

Based on the analysis of various deicing methods, it is concluded that heat removing and melting ice method is effective, and its cost is high; mechanism removing and melting ice method consumes less energy, its cost is low, and it is strongly passive and with too much work, and also restricted by the geographic condition; the natural passivity removing and melting ice method is easy but the result is not so good; other ways are restricted by various conditions and are unable to put into practice. Compared to other methods, heat removing and melting ice method is the most sophisticated, currently, the specific method already used mainly includes over-current ,melting ice method, AC short-circuit current melting ice method, direct current melting ice method, etc. For the transmission line of 500kV or higher voltage, because it is difficult to find the appropriate power source, so AC short-circuit current melting ice method cannot be adopted, but only the direct current melting ice method.