

A Review Paper on Icing and Methods to De-Ice the Transmission Line

¹Deepika Sinha, ²Srijana Bharadwaj, ³Asst. Prof. Vikas Kumar

Department of Electrical Engineering, B. K. Birla Institute of Engineering and Technology, Pilani, Rajasthan, India

Abstract: Ice accumulations on conductors in transmission lines are more common to areas where snow fall is quite an obvious phenomenon. This phenomenon of ice formation can cause severe damage to the transmission line. So to overcome this problem, various de-icing techniques are discussed in details. According to the types of transmission lines, ice melting methods are categorized into ac line de-icing and dc line de-icing. Various methods are described for de-icing technique. Then advantages, disadvantages and comparative study of various de-icing methods is presented.

Keywords: De-icing; Ice Disaster; Deicer.

I. INTRODUCTION

Icing phenomenon on transmission line occurs due to low temperature, freezing rain, and so forth. Ice formation on transmission line is a common natural disaster. Most of the countries of the world like china, southwestern America, North Caucasus in Russia, Japan, Britain, Finland, some part of India are facing problem due to ice formation on transmission line. Serious ice coating will influence the stability and security of power grid operation. So, transmission line de-icing is a major concern issue and should be resolved by different deicing techniques. There are many methods which are being employed to deice the transmission line like mechanical deicing, electric melting ice or thermal deicing, and natural passive deicing methods and many more [1]. Mechanical deicing uses mechanical force to make the ice break and fall off, which mainly contains "ad hoc" method and pulley scraping method. "Ad hoc" is a kind of artificial knock deicing method; it relies on external force to percussion deicing, pulley scraping method is to eradicate the ice by artificial pulling the pulley on the line, which is a feasible mechanical deicing method on transmission lines. The thermal method of deicing uses joule heating effect that heats the icing conductor with huge current so that ice melts.

Natural passive de-icing is a method that is based on the environmental elements of wind, gravity, and temperature variation to make the ice drop naturally without additional energy. In spite of these methods, other methods are proposed such as pulse electric heating deicing, corona discharge de-icing and infrared heating deicing etc. [2].

Current de-icing method is categorized in two categories one is ac deicing and another is dc de-icing which are further selected by characteristic of transmission line and electric grid. Presently, as most transmission lines in the world are ac lines, so ac de-icing methods are considerable studied and the results are significant. In addition, with more and more dc lines having been built during recently years, dc de-icing is becoming a new method. In the paper various methods according to the characteristic of transmission line are introduced in details.

II. A.C. LINE DE-ICING

Most of the countries in the world use ac transmission as the main transmission system. So it is essential to melt the ice for the stability of the power grid. The main method described for de-icing the transmission line is described below.

A. Short-Circuit De-icing:

Short-circuit de-icing is one of the most frequent methods which are in practice. During the melting period, short-circuit current needs to be huge enough so that accumulated ice melts, without exceeding the thermal limit of the conductor [3].

According to the different categories of short-circuit faults, there are three categories of deicing: three-phase short-circuit deicing, two-phase short-circuit de-icing, and single-phase short-circuit de-icing. These methods can be employed respectively for transmission lines, double overhead ground wires and lighting conductors.

The short-circuit de-icing for transmission lines consists of short-circuiting or grounding the line at one end and applying a potential of sufficient magnitude at the other end as to cause ice-melting current on the line. The current during the phenomena is larger than normal current, which makes the icing conductor heated. The key to apply this method is the appropriate power source when considering the conductor types and the different line length. Regular low voltage is used as power source to provide de-icing and current for the higher voltage level transmission line. In case the current is exceeding the thermal limit of the conductor many lines under same voltage level can be put in series.

Short-circuit de-icing is more suitable and effective for the transmission lines that are weak in anti-ice and difficult to reconstruct. However, the disadvantage of this method is the necessity of taking the lines out of service and the plenty of time consumed in the melting process.

Besides, the feasibility of deicing is determined by the power device to supply the required de-icing current. According to reference [4], using 220kV to melt 500kV transmission lines requires more than 1000Mvar reactive power and using 500kV to melt 500kV transmission lines needs more than 2000Mvar.

For the 500kV transmission lines this method is unfeasible because the reactive power energy is limited. Therefore, short-circuit current de-icing, which is limited by voltage and transmission line condition, is not likely to be applied in long transmission lines and high voltage level such as 500kV transmission lines.

B. DC De-icing in AC Lines:

The development of the dc technology and the design of high current controlled rectifier make the dc de-icing feasible and efficient. The dc de-icing is achieved using direct current and suitable for all kinds of voltage level. This method requires the formation of a closed loop using line conductors or a loop of two transmission lines connected in series. The icing conductor must be isolated at both ends from its normal ac supply. Comparing with ac de-icing, the required power source and de-icing current of dc de-icing are much lower as the capacity of dc de-icing only depends on the dc resistance and the length of the transmission line.

1) Fixed dc based deicer:

Fixed dc based deicer consists of ac power supply system, rectifier transformer, silicon controlled rectifier and protection system. The de-icing equipment gets the melting source directly from the ac power. Rectifier transformer is suggested to install between power source and rectifier so that de-icing voltage can be adjusted.

2) Mobile dc power supply de-icing:

In some conditions, many 220kV or 110kV transmission lines only require less than 25Mvar power source while deicing. Under the worst hazardous condition, it is even harder to get the de-icing power from the ac substation. Therefore, the mobile dc power supply deicer is needed. This deicer obtains the power source from removable generators and the de-icing capacity is determined by that of generators. Mobile dc power supply de-icing is limited by the big volume of generators so it's only applied to the transmission lines under 35kV. For 500kV ac transmission line or above, dc de-icing should be considered firstly as the capacity of ac de-icing is limited. However, some particular electronic devices needed for dc de-icing make the cost of dc deicer relative high.

C. On-Load De-icing:

In some condition, some important loads not allowed to be isolated from the network. Short-circuit de-icing requires taking the lines out of service. So it is necessary to use the on-load deicing. The basic theory of on-load deicing makes use of more current on the ice accumulated lines without cutting the lines. Then heating of the selected lines causes the ice to melt. The advantages of on-load de-icing are that the entire loads remains connected to the reduced network, and no additional equipment is added in the melting process. Only the timely switching of lines need to be considered. There are many ways of on-load de-icing such as power flow de-icing, reactive current de-icing and phase-shifting transformer deicing [5].

1) Power Flow De-icing:

Power flow de-icing is that method in which increasing the load current of the transmission lines by adjusting the grids power flow without adding any deicer. After the ice disaster of 1998 in north eastern America, Hydro-Québec developed a de-icing strategy for 120~315kV lines. A computer program has been developed to simulate the ice buildup on conductors and melting the ice using the heat generated by the currents flowing in the conductors. Using simulation tools, different network configurations can be tested and the best sequence of de-icing method can be applied to reduce the ice buildup over the network. The program can serve as an aide to operators during ice storms and as a training tool to better prepare for ice disaster. For radiant type lines, there are several ways to adjust the grid's power flow: outage the parallel lines, increasing the capacity of receiving end, decreasing the capacity of sending terminal, transferring load, lowering voltage level and increasing the reactive power etc. By using other ways to change the power flow of loop network, the results are very limited except the way to cut load. However the loop network has strong supply capabilities, it is necessary to cut two or more lines to change the power flow.

2) Reactive Current De-icing:

Reactive current is injected into the lines creating more heating energy to melt the ice. The method of reactive current de-icing is implemented by installing the shunt capacitor at the power supply side and installing the adjustable reactor at load side. Through adjusting the reactive value of inductor to modify the current in the deicing loop, the transmission line is overloaded and the temperature is rising in order to melt ice [6]. The installation of shunt compensation capacitor and parallel adjustable inductor are convenient with less amount workload. However, extra equipment's are needed and during the de-icing period it is difficult to make a feasible control of reactive power flow especially in the loop network. Generally this method is seldom used in the power system because adjusting the reactive power flow may cause the unsteady problem of the network.

3) Phase-Shifting Transformer De-icing:

Using the phase-shifting transformer as a deicer for the transmission lines has become quite popular because it can be generally used without interfering with service to the lines [7]. Phase-shift transformer can cause an active power circle—one line transmits forward and the other line transmits reverse. So the increased forward transmission current and its value is equal to the phase-shifting current in addition with load current. Which causes Circulating current to flow over a transmission line to de-ice it? Circulating current depends on the line impedance and the degree of phase shift. Under the normal operating conditions this method has the icing conductor melt by adjusting the circulating current of the double circuit transmission lines. But the phase-shifting transformer is additional and more reactive supply is required, which can influence the steadiness of system.

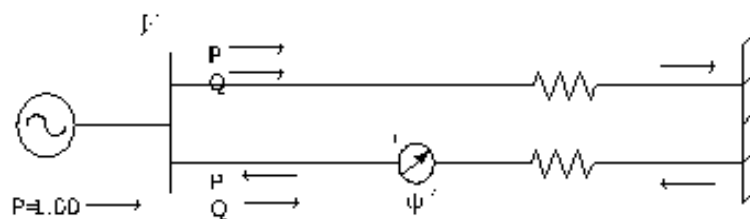


Figure 1 the scheme of phase shifting transformer deicing

III. D.C. LINE DEICING

At present, to melt accumulated ice from dc transmission line, direct current de-icing method is widely used. Because of the control characteristic of HVDC, altering control mode is usually used to melt ice. There are four ways of de-icing methods based on the switching of control modes.

A. Parallel Mode De-icing:

Two thyristor converters connected in parallel is the simplest and the most effective de-icing method. With this, the value of direct current increase up to twice of its level without exceeding the capacity limit of converter. The schematic diagram of bipolar converter in parallel is shown in Figure 2. Using two thyristor bridges in parallel is the natural configuration of the circuit in deicer mode and can provide larger de-icing current timely. For example, the nominal current rating in deicer mode is 7.2kA, defined at an ambient temperature of +10°C [8]. This current rating is beyond the capacity of a single

converter bridge based on present HVDC technology. With two converter bridges connected in parallel, the required direct current per bridge can easily be met, each operating at a nominal current rating of 3.6kA.

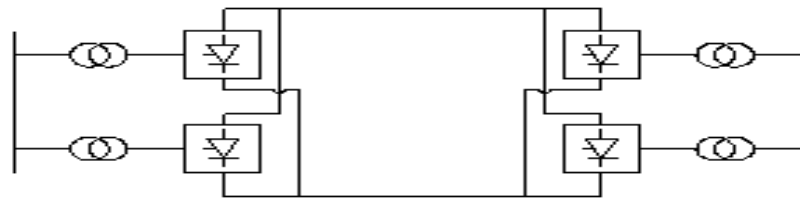


Figure 2 The scheme of parallel mode deicing.

B. Over-Load Anti-icing:

In summer peak, more loads are consumed in HVDC system and the current is nearly close to 4kA, in which anti-icing action can be adopted. As the HVDC project normally has overload capacity beyond 10%, 4.4kA over-load current can be utilized to heat the conductor temporarily [9]. If two polar cannot provide the capacity of over-load transportation at the same time, the polar can be chosen alternately to work in over-loaded conditions. Over-load anti-icing has the advantage of easy operation and no affect in the normal operation of HVDC system. But it is impossible for rectifier to provide sufficient power so the de-icing current may be lower than required.

C. Low-Load Anti-icing:

Using this method to produce the de-icing current, the amount of power source needs to be considered in order to get larger current while consuming less power source. The theory of low-load anti-icing is that the power of two polar flows in the opposite directions: one polar flows forward while the other one reverse. By adjusting the power flow direction of one polar, anti-icing current can be easily produced. Using this method doesn't require high direct voltage but isolates the polar by the operation of bipolar single converter ground return. The low-load anti-icing is easy to implement without doing any mode changes of HVDC system and protection facilities. As the less power source is required, this method causes little influence on the ac system.

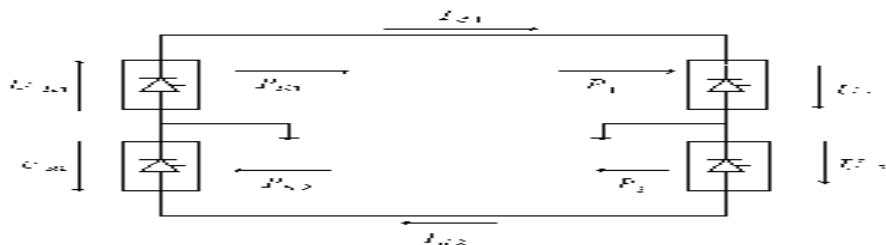


Figure 3 The scheme of low load anti-icing

D. Single converter on-load de-Icing:

When HVDC works in the mode that the power of bipolar flows opposite, the direct voltage of two polar is in the same polarity. Therefore, two lines which outside the ice coating areas are connected to form the mode of single side converter on-load de-icing. By adjusting the position of short-circuit point, the icing conductor can be selected to connect with its relevant side converter to form a de-icing circuit loop. Thus, it is more efficient to de-icing as the power loss between the line outside the short point and other sides converters can be saved largely. This method needs some additional equipment such as short circuited line, isolating switch and related corresponding stations. The scheme is shown in Figure4.

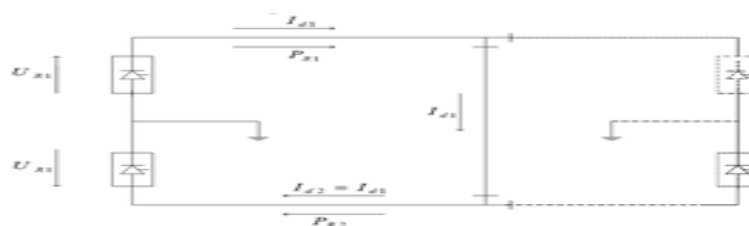


Figure 4 The scheme single converter on load de-icing

IV. CONCLUSION

In this paper a method of ice melting is discussed. Transmission line accumulated with ice both ac and dc de-icing methods can be considered in practice. Ac short-circuit de-icing is used frequently with the advantages of easy controlling and satisfactory results. But the application range is limited by the power capacity so generally it is not used for lines beyond 500kV and the iced conductor needs to be isolated from the network. To prevent important loads from outage and taking the full use of the load current of the transmission line, many on-load de-icing methods are introduced which is functioned by changing the power flow of the network. Power flow de-icing doesn't require taking lines out of service or requirement of any extra equipment. But it is hard to be operated and will probably make the system unstable. And the reactive current de-icing, because the reactive power flow is changed, which can cause voltage instability. The results of phase-shifting transformer de-icing are better when used in parallel double-circuit lines or two split conductor, but transformer is installed additionally. Therefore under normal circumstances on-load de-icing methods are seldom used in practice.

When transmission line with the characteristics of high voltage rating and long distance, it is more appropriate to use dc de-icing. Dc de-icing doesn't need as many power sources as ac de-icing because the capacity of it only depends on the dc resistance and the length of the transmission line. Therefore, it is suitable for all kinds of voltage levels lines especially the high voltage level lines. And dc de-icing is achieved by changing control strategies of HVDC to adjust the melting current. But due to the high cost of the dc deicer equipment, it is not widely applicable at present. In reference [10], dc deicer is studied as SVC which is functioned in the non-ice covered period. However, the present ice melting technology is immature and every method has disadvantages. So some questions still need to be studied in the future.

REFERENCES

- [1] S. Tugang, "Review of development of de-icing methods on transmission lines," Mechanical & Electrical Engineering Magazine, vol. 25, no. 7, pp. 72 – 75, 2008 (Chinese).
- [2] Huang Xinbo , Liu Jiabing , Cai Wei , et al. Present Research Situation of Icing and Snowing of Overhead Transmission Lines in China and Foreign Countries[J].Power System Technology, 2008,32(4) : 23-28
- [3] Maurice H.Christian L, Robert S A, et al. A dynamic programming methodology to develop de-icing strategies during ice storms by channeling load currents in transmission network [J]. IEEE Trans on Power Delivery, 2005, 20(2): 1604-1610.
- [4] Kalinin L P, Soldatov V A. The application of phase-shifting transformers to the power line ice melting[C]. Presented at the Int. Workshop on Atmospheric Icing of Structures, 1990.
- [5] Xinbo Huang; Qindong Sun; Jianguo Ding. An On-Load Monitoring System of Transmission Line Conductor De-icing[C]. Industrial Electronics and Applications, 2008. ICIEA 2008. 3rd IEEE Conference. 891-895.
- [6] M. Granger, A. Dutil, A. Nantel, "Performance aspects of Levis Substation De-icing Project Using DC technology", presented at the 11th Int. Workshop on Atmospheric Icing of Structures, Montreal, Canada, June 2005.
- [7] Déry, J.P. Gingras, "Hydro-Québec De-icing projects", presented at the 11th Int. Workshop on Atmospheric Icing of Structures, Montreal, Canada, June 2005.
- [8] René Cloutier, André Bergeron, Jacques Brochu. On-load network de-icer specification for a large transmission network[C]. IEEE transactions on power delivery, 2007, 22(3):1947-1955.
- [9] René Cloutier, André Bergeron, Jacques Brochu. On-load network de-icer specification for a large transmission network[C]. IEEE transactions on power delivery, 2007, 22(3):1947-1955.
- [10] M.W.Davis, "A new thermal rating approach: there altime thermal rating system for strategy cover head conductor transmission lines. Part III. Steady state thermal rating program continued—solar radiation con-siderations," IEEE Trans. Power App. Syst., vol. 97, no. 2, pp. 444–455, Apr.1978.
- [11] Sisi Li, Yuhong Wang, Xingyuan Li, Weiwei, Guoshuai Zhao, Pengfei He "Review of De-icing Methods for Transmission Lines" International Conference on Intelligent System Design and Engineering Application, 2010.