ANALYSIS AND PREVENTION MEASURES OF TRAPPING OF 1000KV CHANGNAN I LINE

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***Abstract**:* According to the General icing principles of transmission line, the icing flashover process was analyzed under micro meteorology condition. The ChangNan I line is the first 1000kV commercial transmission line of China. So the operating experience is lacked, it is very important to study and analyze the problems arose in the operation and maintain. According to the research achievement of micro meteorology theory of transmission line and icing flashover theory of insulator applied high voltage, a detailed analysis of trapping caused by icing flashover of transmission line insulator was carried out. Furthermore some preventive measures which can provide reference for the production and management part of Power Grid were proposed.

1. INTRODUCTION

A large scale and long term freezing rain and snow weather has been took place in middle and south of Henan Province China, early February 2010. This extreme weather caused a serious disaster for the transmission line in Henan. The 500kV transmission line in Xuchang, Luohe, Pingdingshan, Zhoukou, and Nanyang of Henan Province damaged at different level, such as the damage of tower cross arm, the breakage of transmission line, ground line, and optical cable. The most of the damaged transmission line were direct at East-West, because the north wind often takes place in Henan in winter. The transmission line directed at East-West is vertical with the wind direction. So the windward line was covered by ice, and the galloping of the conductor took place.The ChangNan I line is the first commercial transmission line of China.

2. RESULTS AND DISCUSSION

A trapping fault take place on A phase of The 1000kV ChangNan I line at 12:41 on February 16, 2010 and a successful reclosing was carried out then. According to the analyzed results of traveling wave fault location system, the point of failure located at place which was 28.3km far from the NanYang switch station and 330.4km from the Yangtze River substation. Therefore the point of fault was calculated near the NO.666 tower, and the operating personnel rushed to the scene immediately. Though the live-line plethora check, the flashover trace was found at the No.667 tower. And the fault point was confirmed.

The reasons of ice flashover fault on insulator of transmission line need be analyzed form three sides, temperature, humidity and wind speed.

Due to the influence of the freezing rain, snow, fog and cold weather which continued for a long time before and after the Spring Festival, the atmospheric environment of the mountain where No.667 tower was located is long-term high wind, low temperature, and high humidity. It is equipped with condition contained the temperature, humidity, changes of wind speed, and result in ice-ice melting process. There was a serious icing phenomenon, and the icing insulator flashed eventually. Therefore, considering all factors, the failure should be caused by a general micro meteorology.

3. CONCLUSION

The icing flashover failure happened at tower No.667 of ChangNan 1000kV transmission line, indicate the lack of knowledge on the power grid design for the natural environment, climatic conditions, ice storm characteristics and rules and the dangers. There is inadequate prevention. So more in-depth study of flashover characteristics of ice cover insulator are need. Looking for laws, develop appropriate prevention and preparedness measures to improve the power grid to withstand disasters are also needed.

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***Abstract*—According to the General icing principles of transmission line, the icing flashover process was analyzed under micro meteorology condition. The ChangNan I line is the first 1000kV commercial transmission line of China. So the operating experience is lacked, it is very important to study and analyze the problems arose in the operation and maintain. According to the research achievement of micro meteorology theory of transmission line and icing flashover theory of insulator applied high voltage, a detailed analysis of trapping caused by icing flashover of transmission line insulator was carried out. Furthermore some preventive measures which can provide reference for the production and management part of Power Grid were proposed.**

Keywords-1000KV ChangNan I line； insulator icing flashover reason analysis；preventive measure；

I. INTRODUCTION

A large scale and long term freezing rain and snow weather has been took place in middle and south of Henan Province China, early February 2010. This extreme weather caused a serious disaster for the transmission line in Henan. The 500kV transmission line in Xuchang, Luohe, Pingdingshan, Zhoukou, and Nanyang of Henan Province damaged at different level, such as the damage of tower cross arm, the breakage of transmission line, ground line, and optical cable. The most of the damaged transmission line were direct at East-West, because the north wind often takes place in Henan in winter. The transmission line directed at East-West is vertical with the wind direction. So the windward line was covered by ice, and the galloping of the conductor took place. The ChangNan I line is the first commercial transmission line of China. Although the galloping of conductor was not took place in this disaster, a trapping fault caused by icing was took place. According to part of the research achievement of the key technology project of State Grid Corporation, in 2009, the research on theory of micro meteorology and on-line monitoring platform, the information was collected carefully and the characteristic of time and space was studied, as well as, a depth analysis of the icing flashover fault was carried out from the point of the influence of micro meteorology on transmission line. At last, some niche-targeting preventive measures were proposed, which can reduce the replace probability extremely.

II. FAILURE PROCES

A trapping fault take place on A phase of The 1000kV ChangNan I line at 12:41 on February 16, 2010 and a successful reclosing was carried out then. According to the analyzed results of traveling wave fault location system, the point of failure located at place which was 28.3km far from the NanYang switch station and 330.4km from the Yangtze River substation. Therefore the point of fault was calculated near the 666# tower, and the operating personnel rushed to the scene immediately. Though the live-line plethora check, the flashover trace was found at the 667# tower. And the fault point was confirmed.

III. THE BASIC SITUATION OF LINES AND THE NO.667 TOWER

The whole length of the 1000kV ChangNan I line which contains 719 towers is 358.432km. 238.497km of this line located in Henan province and contain 470 towers the lines cross the Taihang Mountain and Funiu Mountain. The topography mainly contain middle and low mountains, low mountains, hills, piedmont plains, monntain canyons, ridge Kong and river floodplains, etc. This area is complex in the form, multi-collapses, landslides and other geological phenomena. In the section in Henan province, the high mountain account for 32.7%, general mountains for 15.7%, plains for 10.4%, mud area for 5.5%. Henan Province is a warm temperate continental monsoon climate and four distinct seasons which is hot and rainy in summer, cold and less snow in winter. The annual average temperature is between 14.1～15.7℃, and the annual precipitation is 600～1000mm.

The configurations of the 667th insulators are two strings hanged both sides of the phase which was showed in figure 1. The configuration of the insulator was showed in figure 2, and every string has 44 insulators. The length of the insulator string is 10.56m, and the length from the hanging point to the bottom of the drape joint plate is 11.815m. The middle phase string is V-shaped double-string, the length of the string is 10.56m. The length of the V-shape string from the hanging point to the bottom of the joint plate length is 12.355m.

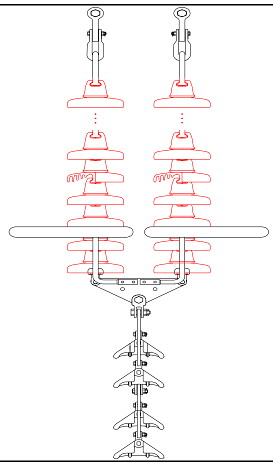

Figure 1. Sketch map of insulator string

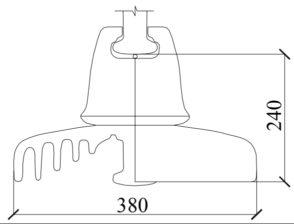

Figure 2. Configuration of CA-597EX insulator

Table 1 the main dimension and characteristics of insulator (CA-597EX)

Diameter/mm	Height/mm	Creepage distance /mm	Weight/kg
380	240	700	23.5
withstand voltage for 1 minute /kV		Minimum breakdown voltage/kV	Mechanical load /kN
Dry	Wet		
95	55	140	550

IV. Confirmation of The Fault tower And The Flashover Point

According to the technical information of the line and the grasping the situation along the corridor, after the trapping, the fault point was estimate in the vicinity of the 666th tower, so the fault point was search in the segment form 655th to Nanyang switching station, after the trapping. Combination of on-site terrain and operating experience, the 666th and 667th towers were decided to the primary towers for investigation.

After careful checking on the tower, the trace of flashover were found on the cap and the shed of the first insulator of small side of the A phase, grading ring of high voltage side and transmission line of small side on the 667th tower. It was identified initially as the fault point caused the trapping of the line, and it does not affect the operation of the transmission line.

The figure 6 shows the A phase where flashover took place. The burn location of the insulator and its situation were found in the red circle. The figure 7 shows the C phase where flashover took place. The figure 9 and 10 show the flashover point of the high voltage side.

Figure 3. Icing condition of ground along the 666～667th line

Figure 4. Ice shedding sample of 667th

Figure 5. Icing shedding sample on grading ring of 667th

Figure 6. Icing condition of insulator and cross arm of A phase after flashover(front side is small side)

Figure 8. The flashover spot of A phase small side insulator of 667th

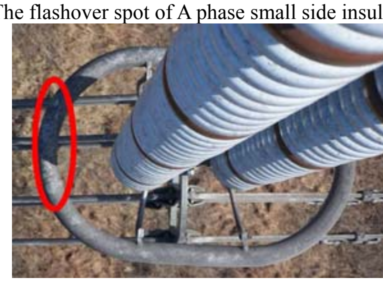

Figure 9. Picture of flashover spot of grading ring of 667th

Figure 11. Picture of flashover spot of transmission line of 667th

V. THE INFLUENCE OF MICRO METEOROLOGY ON ICING OF THE TRANSMISSION LINE

A. The Theory of Micro Meteorology of Transmission Line

At present, the researches on the micro meteorology of transmission line are limited to a small area and a thin layer of air near the ground atmosphere, as well as the dynamics of atmosphere. To the small side, a field, or even the area around a tree is a micro-climate area, to the big perspective, a area of tens or even hundreds of km in radius can be called a micro-meteorological zone.

The research on micro meteorology of transmission line has been carried out with a certain range. The characteristic is as follow:

(1) The wave length or diameter of the weather system is small, and duration time between newborn and demise is short. The aclinic range is a few hundred meters to tens kilometers, and life time is only a few dozen minutes to two or three hours. Another situation is that the aclinic range is tens kilometers to two or three hundreds kilometers, and the life time is one hours to ten hours.

(2)The gradient of meteorological factor is large and their performance is strong. When the squall line wind is crossing, the instantaneous change in pressure, is up to about 1 hPa/m, the temperature change up to 10℃ every 15 minutes, the wind speed can be reach several meters per second, the vertical speed is generally up to 1～10m/s and even be observed to more than 50m/s compared with several centimeter of the large scale weather system, and this is at the same level with the horizontal velocity.

(3)Non-geostrophic balance and non hydrostatic equilibrium. The vertical gradient in pressure can't balance with the downward force of gravity. That is to say, the static equilibrium can't be reached and the force of earth rotation can't balance with the horizontal pressure gradient force, as well as, the geostrophic equilibrium can't reached. The horizontal acceleration, the force of earth rotation and horizontal pressure gradient are in the same order of magnitude, which caused wind can't be parallel with isobar.

With the help of the fluid dynamics, the researches on micro meteorology of very small area were carried out. Under the action of various fore, the status of fluid (air) and the interaction between fluid and solid small, fluid and fluid, fluid and other movement patterns, were carried out. The main basis is Newton's laws and the law of conservation of mass.

B. The Influence of Meteorological Condition on Icing of Transmission Line

The icing on transmission line is a comprehensive physical phenomena affected by temperature, humidity, the convection and circulation of cold and warm air, wind and other factors. There are many factors impact the icing of transmission line, and the main factors are the weather condition, terrain and geographical condition and altitude. The most important factor is the weather condition. The necessary meteorological condition for icing on transmission line contain a temperature which is cold enough to freeze, that is the temperature is below 0℃, high humidity, that is the air relative humidity is generally above 85%, and certain wind speed which can move the water droplets in air.

The maximum icing speed (density of objects on unit cross section per unit length or the quality rate of increase) was limited by the velocity density of impacted particle which can be known as the droplet in the air. The velocity density of impacted particle is F, which can be express as the product of mass concentration (ρ) of particle and the effective speed (υ) of the particle related to the object which can be insulator, fitting and conductor. The icing speed can be express as the rate of change of ice mass (M) accumulated on the object. The relationship can be express by the equation (1).

$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 w \rho \upsilon A \qquad (1)$$

Where, A is the effective cross sectional area of object. The factor α1, α2 and α3 are less than 1. They represent a process of possible maximum reducing value dM/dt. The factor α1 is the collision rate or the average collision rate of the particle. That is the ratio of density of the collision particle and the particle flux density of the air. However, this parameter changes with particle size because small particles with the air flow away more easily, so the parameters will be small. It can be shown as figure 10.

The factor α2 is a rate of combination or the means rate of combination of the particle in the object and the object. The factor α3 is the freezing rate, meaning the ratio of ice particle flux density and the combination particle flux density.

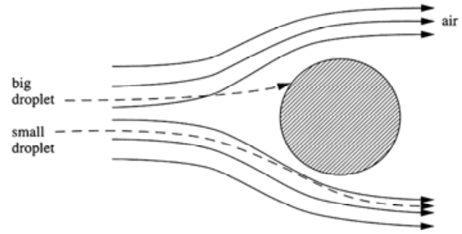

Figure 12. The direction of flow and the track of droplet around the cylinder

VI. ANALYSIS OF ICING PROCESS ON INSULATOR OF NO.667 TOWER

Due to the influence of the freezing rain, snow, fog and cold weather which continued for a long time before and after the Spring Festival, the atmospheric environment of the mountain where No.667 tower was located is long-term high wind, low temperature, and high humidity. It is equipped with condition contained the temperature, humidity, changes of wind speed, and result in ice-ice melting process. There was a serious icing phenomenon, and the icing insulator flashed eventually. Therefore, considering all factors, the failure should be caused by a general micro meteorology, and the depth analysis is made as follow.

A. *Weather Condition of Icing*

The fault took place at February 16. The patrol officers found the body of the No.666 and 667 tower have a slight icing with the thickness of 5 mm, during the special patrol on February 14.

After consultation with the meteorological department and local residents, there are snow, wind with unstable speed(3~5), and the temperature is -7 ℃ ~ -3 ℃ in 2010, February 14 to 16 am. The snow stopped at February 16 07 am. There was northwest wind (4～5) accompanied snow at around 10 o'clock. And the flashover fault took place at 12:41 that day.

B. *Ecological Factors of Icing*

The investigation section is form 658th to719th, and the topography of the section 658-670 is high mountain and high hill area. There is abundant precipitation in this along area every year. The climate is humid in small scale. There aren't chemical industries, quarries, mining and other polluting production workplace, so the design of the polluted area is level II. Furthermore, under the UHV AC pilot project design documents, transmission line insulation configuration is higher than the actual contamination situation by a class, which enhances the ability of anti-pollution.

C. *The Topographic Factor of Icing Occurrence*

According to the definition of icing in reference [1], the icing intensity can be express as:

$$I = EaEvw \quad (2)$$

Where, I is the intensity of ice, kg/m2s ; Ea is freezing coefficient, Ea=1 for the dry growth, Ea<1 for the wet growth; E is the collision efficiency; v is the wind speed, m/s; is the content of liquid water in air, kg/m3 .

The figure 11 shows the profile chart before and after the 667th tower. From these figure, it easy to know that there is an approximate narrow and broad plain, about 5 km wide South-north, along the East-West direction at the middle of this section. The 667th tower located at the highest altitude of this section. The elevation rise rapidly and then decline. It is the type of microclimate area in the rapid uplift of the micro-topography terrain. The direction of cold air from the North gradually changed from the level of oblique when meet the upward elevation of 665 ~ 667 of the mountain, and the wind speed gradually increased. At the same time, the humid air lift valley to the mountain top and wind speed, humidity Peak, and then gradually slow down over 667, shown in Figure 12. Changes in meteorological parameters increased the formation of ice on insulator, leading to transmission line icing load increases. The patrol officers have a personal experience during they patrol from the foot of the mountain road to the place at tower 667th. With the increase of the altitude patrol officers climbing, the wind speed v increase gradually from small to big, the temperature increase gradually from high to low. On the peak, humidity w is relatively large. According to the equation (2), the larger of the wind speed the more ice. So, the icing is gradually serious with the rise of terrain of the 665th~667th tower.

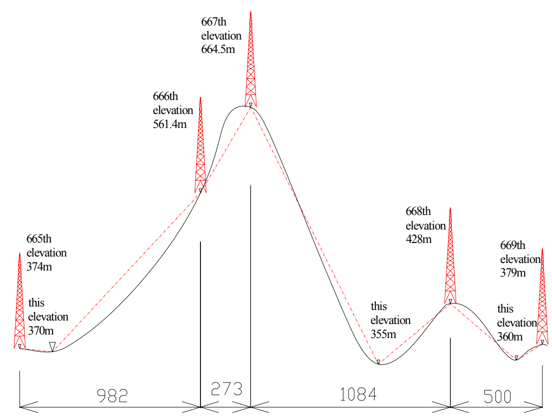

Figure 13. Profile chart before and after the 667#

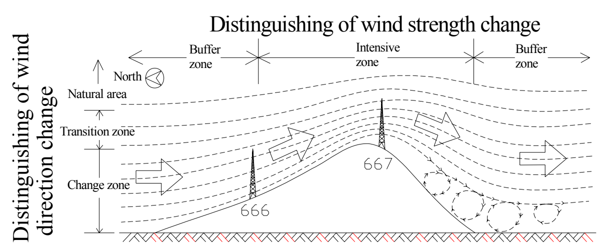

Figure 14. The sketch map of lifting of flow air when meet the steep hill

To sum up, the weather in the surrounding factors, ecological factors, combined effects of topographic factors, this section of easy-to-north direction of the wind in the air formed under the uplift, strengthen, humidity increases, so the formation of small-scale lead to cover micro-meteorological area cause rapid formation of ice.

D. *The Formation of Icing Flashover*

It was a longer period (February 7 ~ February 14) of continuous rain snow weather before icing flashover occurred. The air humidity is high, and there is some weak ice on the insulator surface. But the sheds of the insulators can not be connected. In the time slot of February 14 to 16, there is snow accompanied northwest wind (4～5). The of trapping is 12:41 pm. This time is the noon, so the temperature has been picked up, and the surface of ice on the insulator begun to slowly melting. The water of the melting snow formed water film, and a short channel was formed on the insulator. As the temperature increased further, the water film on insulator surface is thickening, and the degree of moisture increased gradually, leading to a rapid increase of leakage current on the snow surface. The partial arc firstly formed at the cap the first insulator (low side) connected to steel and the place between the grading ring and the insulator tip of the lower part of icicle. During this period, insulator strings may also have other partial arc, followed by partial local electrical arc that causes ice to melt off. The leakage current intensity was increased by the melted snow. The arc is stretched or extended upward, eventually leading to arc connectivity, resulting in tripping accidents. At the flashover instant, a large area of ice was shedding from the insulator surface caused by the high-temperature of the arc. The shed of the porcelain insulator was dried, and the flashover channel was eliminated naturally. The insulated performance of the insulator string restore to a greater degree, so a successful line reclosing is carried out.

VII. CONCLUSION

Looking for laws, develop appropriate prevention and preparedness measures to improve the power grid to withstand disasters are also needed. According to the characteristic of icing, some preventive measures and proposals can be proposed as follow.

1) The video surveillance system can be established at tower No.667. The current 3G communication technology may be used to monitor circuit operation real-time. While a professional monitoring station could be set up at the same topographical and meteorological characteristic. The operational department can take remedial measures to avoid damage to line trapping cause by icing or adverse weather. On the other hand, it can provide convenience for collecting and accumulating long-term meteorological changes, videos, images and data information for transmission lines, which provide the basis for the design and operation and maintenance. And it is easy to carry out related technology.

2) The insulators with large diameter could be used. It can block the path icicle bridge by change the insulator in to insulator with large diameter at the top, middle and bottom of porcelain insulator string suspended in a straight line. The type '3+1' can be used in 500kV transmission line. That is to say, the big diameter insulator is used between three common insulators. The operational result is good, from the situation in recent years.

3) Consider to use the method of inclined suspension insulator. We can adopt the 'V' type and '∧' type or increase deflection angle along the direction of the insulator string line. It can block the icicle bridge between adjacent insulator chip connectivity, to a certain extent. Through that the icing flashover voltage can be increased.

4) Application of technology by climbing skirt. On the insulator string, large diameter silicon rubber umbrella group are installed in every 5 to 6 insulators, the umbrella group can increase the diameter of insulator, prevent the surface of insulator string was covered completely. The measure was experimental used on the icing tower for the first time in 2010 April. It has not affected the normal operation of lines, and the anti-icing effects can't be tested now.

5) The design department should search detailed information, survey of icing, lightning, and other micro-meteorological zone, when the transmission line is designed. The design line should avoid the micro topography, microclimate areas as far as possible. If it can't avoid and need to cross which subject to condition, some necessary measures should be taken. Or section design is need according to the actual situation. The tower in the serious icing area should be designed as enhanced line tower, base on seriously studying the long-term reliable observations of ice and considering a revised data.

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