Study on icing and its trip laws of transmission lines in Shanxi Power Grid

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Abstract. Overhead transmission lines are important carriers of electric energy transmission. Their icing, galloping and shedding in winter and spring seriously threatened the safe operation of Shanxi power grid. Especially in the recent years, compact lines and double circuit lines on the same tower, typical types of overhead transmission lines in Shanxi Power Grid, were affected by frequent trips induced by icing, galloping, and shedding appeared in their conductors repeatedly, which seriously reduced the capacity of power energy transmission in Shanxi and caused trillions of power load losses. Through detailed investigation and analysis of the characteristics and historical fault cases of compact lines and double circuit lines on the same tower in Shanxi Power Grid, the key causes and main laws of two types of lines in Shanxi Power Grid are clarified, which could provide support for the follow-up line anti-ice technical transformation and capacity improvement.

1 Introduction

Due to the special topography and coal resources, transmission lines in Shanxi power grid have special achievements and features, including the first Ultra-High-Voltage 1000kV line in our country[1,2]. However, in recent years, the transmission lines in Shanxi Power Grid are frequently affected by trips induced by icing, which mainly include galloping[3-5] and icing shedding. Especially for two special type of lines, compact lines and double circuit lines on the same tower, the impact is more serious. Up to now, there are 5 500 kV Compact lines and 3 500 kV double circuit lines on the same tower, with a total length of 924.73 km and 1765 towers. These lines involved are shown in table followed. Compared with other provinces, the proportion of these two types of lines in the whole regional power grids is relatively larger.

Compact and double circuit lines on the same tower have the characteristics of small corridor and land saving. Compact design is adopted for 500kV Lvmeng I line, shuoyun line, Xinshi I line, II line and III line. Double circuit design on the same tower is adopted for 500kV Fengyun I line, II line, zuolu I line, II line and Xuanxin I-2 line. However, due to the characteristics of small phase to phase distance of conductors, compact lines are more sensitive to ice damage, and are prone to trip fault caused by galloping and de icing jump. At the same time, the cost of transforming compact and double circuit lines on the same tower into conventional lines is high, while the compact and double circuit lines on the same tower which are located in high risk galloping area, heavy icing area and micro topography area and have not been reconstructed in time may galloping and de icing jump for many times; the line design specification does not consider carefully the de icing condition check of conductor and ground wire and the value of horizontal deviation, which leads to dissatisfaction with the typical tower type.

Table 1. 500kV Compact lines and double circuit lines on the same tower in Shanxi Power Grid

Line name	Line type	Number of towers	Mileage /km
Lvmeng line I	Compact	284	124.19
Shuoyun line		409	172.18
Xinshi line I		208	92.65
Xinshi line II		217	96.35
Xinshi line III		215	96.11
Fengyun line I and II	Double circuit on the same tower	144	128.26
Zuolu line I and II		205	181.84
Xuanxin I and II		83	33.16

To meet the requirements of trip protection, it brings great threat to the operation of relevant lines. At the same time, limited by the scale of governance, power outage and other factors, it is relatively difficult to fundamentally improve the overall intrinsic safety level of power grid in the short term. Based on the basic

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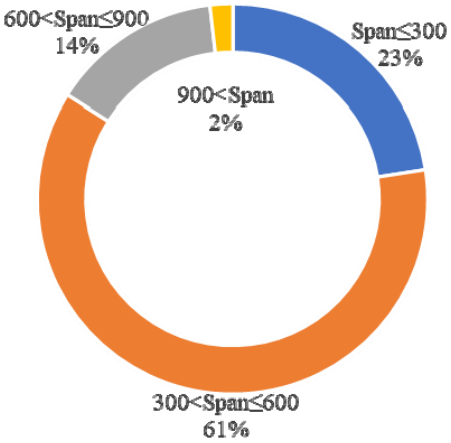
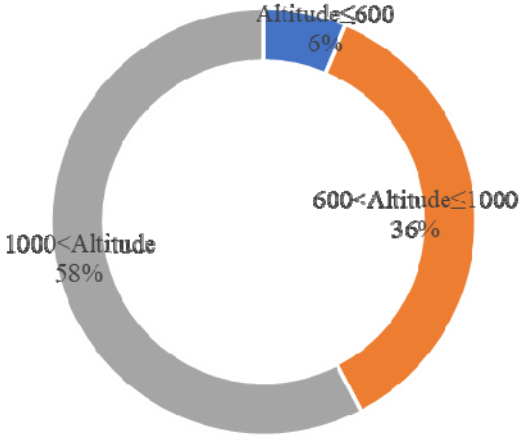
situation of Shanxi compact and double circuit lines on the same tower, it is necessary to analyse the historical fault cases in detail, clarify the causes and laws of disaster, and consider installing monitoring and prevention devices, to fundamentally reverse the passive situation of ice disaster prevention.

The span and altitude distribution of the two types of lines in Shanxi are shown in the figure below:



(a) Pie graph of Span distribution(unit: m)



(b) Pie graph of altitude distribution(unit: m)

Figure 1. Span and altitude distributions of compact lines and double circuit lines on the same tower in Shanxi Power Grid

It can be seen from the figure that most of the spans of the two types of lines are between 300 and 600 m, accounting for 61%, and the sections with large spans (above 600 m) account for 16% in total. In terms of altitude distribution, the number of towers whose altitude is above 1000m is more than 58%, followed by those towers with altitude between 600m and 1000m, accounting for 36%, and those below 600m are the least, only 6%.

2 Icing and its trip laws

According to the actual situation, the disaster statistics of compact lines and double circuit lines on the same tower in Shanxi are shown in Table 2. Compared with Table 1, it could be easily found that almost all the lines of this type have trip faults caused by icing.

Table 2. Historical galloping and icing shedding cases in Shanxi Power Grid

Order number	Name of lines	Tower section	Icing condition	Number of figures
1	Fengyun line I and II	#76~#77	≤5mm	Figure 1
		#87~#89	>5mm	
2	Shuoyun line	#64~#65	≤5mm	Figure 2
3	Xinshi line I	#127~#132	≤5mm	
4	Xinshi line II	#125~#131	≤5mm	
		#157~#161	≤5mm	
5	Xinshi line III	#127~#134	≤5mm	
	Zuolu line I	#179~#180	>5mm	
7	Zuolu line II	#40~#41	>5mm	
		#184~#185	>5mm	
8	Xuanxin I and II	#15~#18	≤5mm	Figure 3

The topographical and geomorphic conditions belong to all the fault line sections are analysed, as shown in the following group of figures.

According to the cases data, it was obvious that the following correlation characteristics and rules between the galloping and icing shedding sections of compact lines and double circuit lines on the same tower, and the topography and weather conditions at that time.

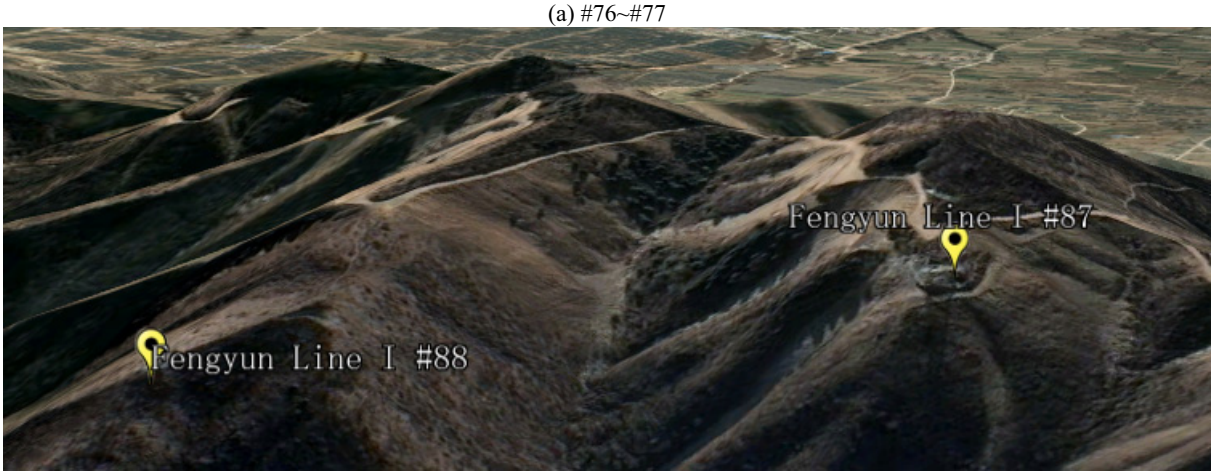
(1) The galloping and icing shedding sections were mostly in micro topography and micro geomorphology areas, which possessed main characteristics, which are alignment across narrow pass or along the ridge, rather than plain or open terrain in the traditional sense.

(2) When galloping or icing shedding occurred in the fault line sections, those were not the dominant wind directions in the large scale that were perpendicular to the line alignment, but the special "diversion wind direction" in local areas were, which was formed due to the interaction of the external surface trend of the mountain or low-lying gullies. It could cause the supercooling water droplets in the air to adhere to the overhead conductor and icing in it.

(3) By comprehensively comparing the weather conditions and topographical features of icing shedding in #87 ~# 89 of Fengyun line I and II, #40 ~ #41 and #184 ~ #185 of Zuolu line II and galloping in other lines, it was clear that heavy icing and galloping are easy to occur on windward side of high altitude (altitude > 1200m) and leeward side of compact lines and double circuit lines on the same tower in Shanxi Power Grid,

while galloping is more likely to occur on leeward side (altitude ≤ 1200m) Or the line sections in the area with obvious fluctuation.

(a) #76~#77



(b) #87~#89

Figure 2. Topographic map of historical fault line section of Fengyun line I and II

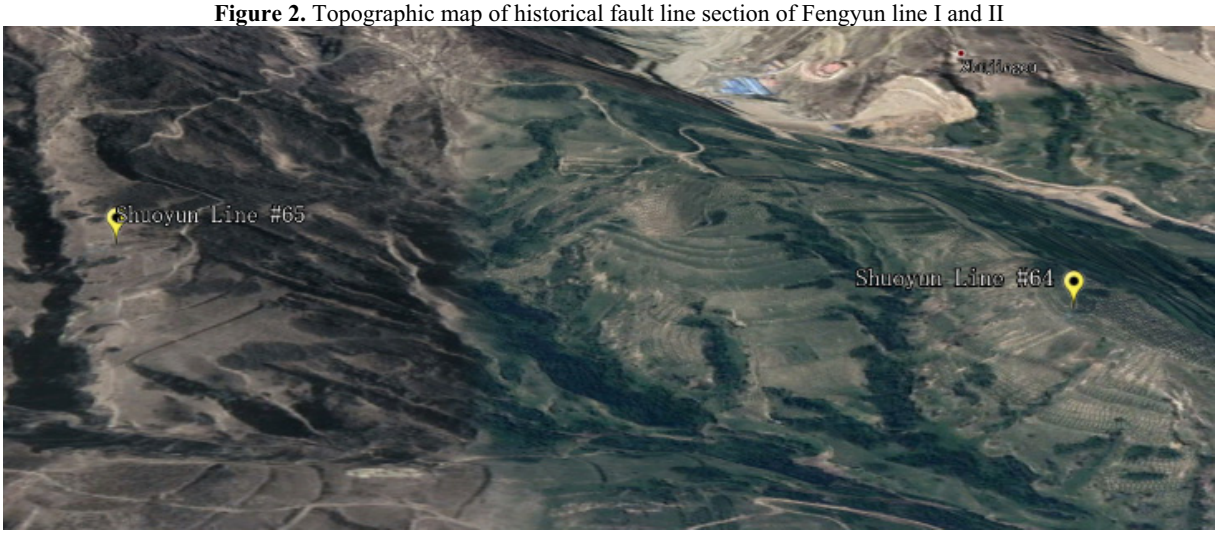


Figure 3. Topographic map of historical fault line section of Shuoyun line

Figure 4. Topographic map of historical fault line section of Xuanxin line I and II

3 Conclusions

Through detailed investigation and analysis of the characteristics and historical fault cases of compact lines and double circuit lines on the same tower in Shanxi Power Grid, the key causes and main laws of two types of lines in Shanxi Power Grid are clarified:

1) Alignment across narrow pass or along the ridge are the main factors to bring out galloping and icing shedding in Shanxi Power Grid.

2) Heavy icing and galloping are easy to occur on compact lines sections and double circuit lines sections on the same tower with high altitude (altitude > 1200m).

These conclusions could provide support for the follow-up line anti-ice technical transformation and capacity improvement.

Acknowledgement

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