Tower head modification with V-insulators strings to prevent inter-span phase contacts during snow shedding effects

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***Abstract*- This paper presents a practical approach to reduce probability of inter-span contacts caused by snow shedding. Field experiences show that during periods of snowing towers are exposed to short circuit events if upper and lower conductors lie in vertical disposition. Prediction of snow quantity is practically impossible. In order to prevent short circuits between phases a re-arrangement of conductors' disposition on the tower was performed in a way that no conductor lies in vertical disposition. This can be achieved by using composite insulators assembled in a V string which represents a possible solution of increasing the line reliability.**

I. NOMENCLATURE

Transmission lines, snow shedding, V-insulators strings

II. INTRODUCTION

As regards climatic conditions Slovenia proves to be a very heterogeneous country. A part of Slovenia where the Mediterranean and alpine climates meet is largely subjected to icing. In the continental part, additional loads in the form of snow frequently appear; mostly wet snow during thawing weather is predominating. This is causing severe problems during line operation.

The majority of the Slovenian 110 kV grid is composed of double circuit lines with vertical configuration of cross-arms. Most of the towers' upper and lower cross-arms are of the same length while the central one is longer. The distances between phase conductors and a ground wire in the middle of the span are designed according to the Slovenian national regulation. Like in the other parts of Europe the distances between conductors are based on their disposition and sags.

In winter 2003, the owner of the 2x110 kV line registered several short circuit events. Analyses of line distances get from protective relays and phase disposition on the line showed that the inter-span contacts occurred due to snowing between the lower and the upper phases. A study of line geometry and a calculation of static conductors' sags for different loading cases showed that some spans, especially those exceeding 310 m, are more vulnerable to snow shedding.

In order to prevent similar problems in future and increase reliability of power delivery, the Utility decided to take the necessary measures to achieve this goal. More solutions were proposed, e.g. re-sagging of the overhead line, extending cross-arms and use of phase to phase spacers.

After several analyses the new solution was put up. Considering the tower cross-arm length it is possible to change a classical insulator string on the upper cross-arm to a V string made from composite insulators. The upper conductors are moved toward the tower body, avoiding the vertical disposition with the lower conductor. With this modification the probability of inter-span short circuit events decreases and the maintenance of line remains unchanged.

III. LINE DESCRIPTION

The observed radial 2x 110 kV line was built in 1975. The towers are of steel lattice construction. Dimensions of the tower head type are shown in Figure 1.

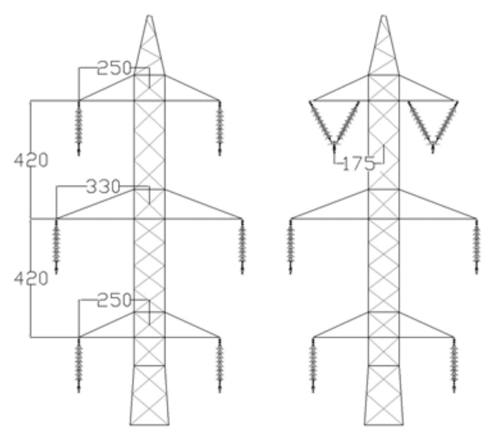

Fig. 1: Tower head geometry.

The line conductors are ACSR 240/40. Conductor diameter is 21,9 mm. The average span of the line is 273 m. According to the national legislation the transmission overhead line is static and the tower head geometry is designed to bear maximal normal load on the conductors. The load in N/m is calculated as per equation (1)

$$g_a = k\,1{,}8\sqrt{d}\ , \qquad (1)$$

where d is a conductor diameter given in mm, and k is a load parameter. They present a load factor on line and could be 1, 1.6, 2.5 or more. The observed line is divided into two sections with *k* equal to 1 and to 1.6 which using equation 1 gives the load of 8,4 N/m and 13,5 N/m, respectively. No load type is included in the equation. In order to compare the design normal load with field observations of load thicknesses obtained by the maintenance people on site, a load calculation was made considering different load thicknesses and types. Four types of load were assumed: ice, rime, wet snow and dry snow having different specific weight. The outer diameter in Fig. 2 is a complete diameter of a conductor covered with load.

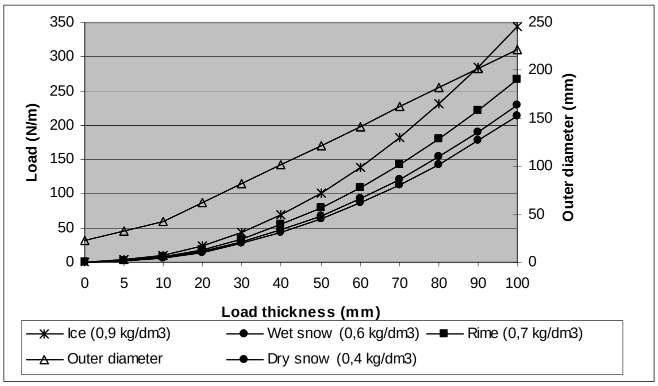

Fig. 2: Additional loads for different load types and load thicknesses.

From Figure 2 it can be seen that in case of design load of 8,4 N/m the equivalent ice thickness is 9,5 mm, rime thickness is 11,5 mm, wet snow thickness is 13 mm and dry snow thickness is 17,3 mm.

In principle, with this load being present on conductors, the tower vertical distances between lower and upper conductors should satisfy, if on the observed span additional load is present and on the other spans there is no load.

However, field experiences on the overhead line show that most problems occur during snowing and shortly after it. It can also be affirmed that the wet snow outer diameter of 47,9 mm was exceeded. This means that the conditions allowing span contacts were fulfilled. In further calculations wet snow was brought into focus. A new value of 33,6 N/m of maximal load for sag calculation was foreseen. This means that the complete conductor diameter covered with wet snow was 89 mm. We assume that higher loads are less possible.

III. Span sensitivity

The sag calculation was made according to Wysic [1]. The sags were calculated in case of an local load only in one span of a tension section. This approach to the problem is still a static one compared with approach known from the references [2, 3], witch were made for similar overhead line. In that were studied complex dynamic effects during snow shedding effects. Numerical calculations show that the conductor starts moving immediately after the shedding takes place. After the oscillation the conductor reaches a new state. The conductor vertical disposition amplitude depends on the scenario we used. Usually, in the ice scenario load quantity represents a boundary condition.

Field experiences show that it is very difficult or impossible to determine load quantity in a short time period. It varies from case to case. So we transfer the problem to a more static point of view. Length distances got from protective relays show approximate locations of inter-span contacts. Data obtained from protective relays show that contacts happened in spans with length over 370. The main goal of calculation was to evaluate the range of span length where probability of contacts is high because of snow shedding effects.

The sag calculation was done for different additional loads and line spans. The load factor was varying in range from 0 to 4. Differences in sags for spans in observed tension section are shown in Figure 3.

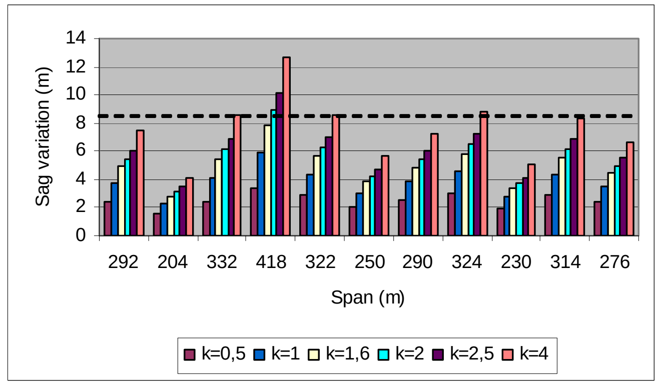

Fig. 3: Sag variation in span at different additional load.

The horizontal dash line represents a vertical distance between the upper and the lower cross-arm. This distance also indirectly represents the load parameter for which the transmission line has been designed. In our case this is 1,6. If additional load exceeds this load, the sag differences can be greater than the vertical distances and a short circuit can occur.

Based on a sag results analysis, line spans are divided into four groups. These groups represent the span length sensitivity to the additional load. Table 1 show span groups and gives a sensitivity description.

TABLE 1
SPAN CATEGORIZATION REGARDING SPAN SENTITIVITY

Group	Span length	Span sensitivity
1	Over 370 m	Very sensitive to minimal exceeding of the design load
2	370m -310 m	Sensitive to exceeding of the design load
3	310 m- 250 m	Less sensitive to snow loads
4	Under 250 m	In principle no problems occur

Regarding our tower configuration spans over 370 m are very vulnerable to snow shedding effects. The Utility decided to perform measurements on the spans over 310 m length.

IV. Tower modification

In order to prevent short circuits between phases a rearranging of conductors' disposition was performed on the tower in a way that neither conductor lies in a vertical disposition. This was achieved by using composite insulators assembled in a V string. Figure 4 shows the insulator V string. As it is evident from the Figure, standard line equipment was used.

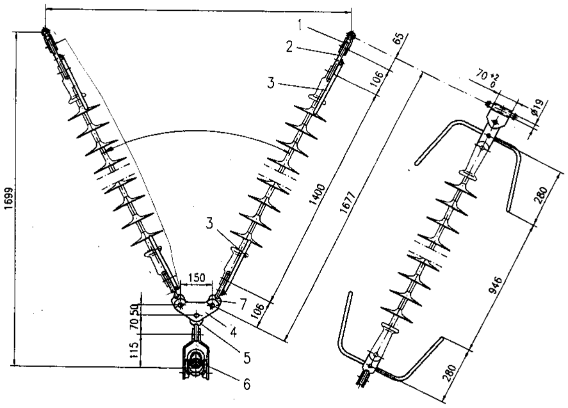

Fig. 4: Insulators V string geometry.

When designing such an insulation string on the existing line, the following items shall be taken into consideration:

- minimal safety distances between hot and ground parts of tower,
- tension tower geometry,
- minimal distances between conductors,
- length of existing cross-arms
- weight and wind spans and
- insulator mechanical strength.

All the above mentioned items had to be considered in a detailed design on existing 2x 110 kV transmission overhead line. Final design of opening angle 63° was used to cover the complete transmission line. As can be see from Figure 1 the upper conductor was moved 750 mm away from the vertical position. The horizontal phase distance between the upper conductors, and the conductors and the earth wire was designed to the minimally allowed one. In order to get a better compromise regarding minimal safe distance between hot parts of the V string and the tower body, and the opening angle between composite insulators, arching horns instead of an arching ring were used.

V. Conclusion

The study of the existing line geometry and the calculation of conductors' sags for different load cases showed that some spans are more vulnerable to snow shedding than the others. The supposition was that during short periods of snowing, spans over 310 m length represent a cause of line interruption.

Fig. 5: Suspension tower after modification.

With rearrangement of the conductors' disposition on the selected towers the probability of a short circuit between phases can be decreased. The conductors' disposition was made by composite insulators assembled in V strings. The line elements were standard and maintenance remained practically unchanged.

The experiences gained in snow shedding resulted in a different design of new transmission lines. The average span shall be lower and if possible, the conductors' disposition should not be vertical. Compact towers' lines with vertical conductors' disposition should be designed carefully.

VI. References

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