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A Novel Approach for Increasing the Reliability of Power Transmission Lines in Galloping Conditions

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Iran SUMMARY

Generally, due to installation in the outdoors, power transmission lines, are constantly influenced by their surrounding weather conditions. Sometimes weather conditions can lead to problems in power system operation and defects on the power network. Therefore, for improving continuity of supply in electricity distribution and prevention of unwanted power outages, it is necessary to prevent the occurrence of weather related problems as much as possible. One of the atmospheric factors that threaten the electrical power delivery continuity is the snow or ice accumulation on transmission conductors, especially in mountainous and cold regions, and consequently the occurrence of galloping conductors. Although special criteria in the design of overhead transmission structures, the line routing, and the tower spotting will be considered until the above-mentioned problems reach their lowest design limits, possible design errors, implementation of Power Line, and even changes in weather conditions can result in possible problems during operation. This study, performed in three phases, was undertaken to provide solutions to problems caused by accumulation of snow and ice on the Shariati-Attar 132 kV transmission line in Iran power network. In the first phase, the problems associated with the accumulation of snow and ice on transmission line's conductors and solutions were reviewed. In the second phase, each of the solutions mentioned in the first phase were examined at the executive level and by experience in implementation of the solutions. In the third phase, according to the modeling was done, technical analysis and then economic analysis was carried out. Finally, the overhead transmission line, considering the optimum final solution, was modeled in the PLSCADD software and the galloping behavior was studied after applying the final solution.
A novel solution has been investigated and implemented in the existing transmission line using a hybrid solution with interphase spacers and counter weights.

KEYWORDS

Power transmission line, icing, interphase spacer, counter weight, galloping, weather conditions

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1. INTRODUCTION

Galloping of iced conductors has been a design and operating problem for electric utilities since the early 1900s. Over the years, it has been the subject of numerous investigations and research programs, resulting in better understanding of galloping mechanisms and in the development of devices and procedures to combat its effects.

Operational history showed unwanted power outages in parts of the Shariati-Attar 132 kV transmission line in cold seasons that caused electricity service interruptions, an increase of Energy Not Supplied, reduced reliability, incurred damages, and depreciation of high voltage equipment which resulted in financial losses.

It is necessary as a case study, that the initial conditions of the overhead transmission line are accurately identified by examining existing documents, technical specifications of overhead transmission line operational records, region topology, climatic conditions, developments in the power network, and field surveys; then by identifying, studying, and determining strengths and weaknesses of methods and experiences of other countries and international achievements, appropriate solutions were offered in order to reduce the accumulation of snow and ice on the Shariati-Attar 132 kV transmission line.

2. TYPES OF OVERHEAD LINE CONDUCTOR VIBRATIONS

Overhead line conductor vibrations include Aeolian vibration, Sub-conductors oscillations, and Galloping. Galloping has caused various kinds of structural damage in overhead lines. Some types of damage result directly from the large forces that galloping waves or loops apply to supports.

For example, cross arms have failed on both wooden and metal structures. Conductor ties on pin-type insulators have been broken and support hardware has failed. In other cases, cotter pins have been damaged and insulator strings have consequently uncoupled. Galloping requires moderate to strong wind at an angle greater than about 45° to the line, a deposit of ice or rime upon the conductor lending it suitable aerodynamic characteristics, and positioning of that ice deposit (angle of attack) such as to favor aerodynamic instability. The ice, wet snow or rime deposit has to have strong adhesion to the conductor. Factors influencing galloping are as follows:

- Ice accretion type and shape (eccentricity, weight, aerodynamic properties)
- Wind velocity (with limited effects of turbulence and orientation as detailed)
- Conductor self-damping (vertical, torsion) in the low frequency range (including span end-effects)
- Span lengths (including all spans of a section) and section length
- Longitudinal stiffness at attachment point on tension tower
- Yoke plate assembly (tension and suspension tower) (torsional stiffness effect)
- Number of sub-conductors and their arrangement
- Sub-conductor spacing
- Sagging conditions (effect on vertical frequencies)
- Spacers (kind of spacer, location, eccentric weight effect, conductor constraint effect)
- Presence of retrofit devices (all kinds including interphase methods)
- Angular orientation of ice in the presence of wind
- Ratio vertical/torsional frequency for each mode, in the presence of wind

Many investigations have been performed to determine the non-dimensional groups of properties relating to the above factors which provide the best candidates for a general approach to galloping.

Obviously, the mechanical and aerodynamic properties of the iced conductor are very important but they are properties over which the designer has little control, except by the use of certain devices.

3. A CASE STUDY

In order to problem solving in one of the Utility companies, this study was done on one of the power transmission line which has been affected due icing during previous years as a pilot project. This overhead line was comprised of 311 kilometers of 132 kV AC line with ACSR Oriole conductor, located in mountainous regions. It was constructed with double circuit towers of vertical configuration, including 266 suspension towers (Type MS tower) and 94 tension towers (Types T30 tower, T60 tower and T90 tower). Figure 1 shows accumulation of ice and snow on a tower, insulators, and conductors. Also, Tables I and II show power outage occurrences on this power line.

Figure 1. Accumulation of snow and ice on the lattice tower, insulators and conductors

Table I. Incidents Reported on Shariati – Irankhodro OHL due icing

Failure Date	Duration of power outage [hh:mm]
December 29, 2008	0:42
February 26, 2011	3:53
February 28, 2011	0:45
February 28, 2011	0:11

Table II. Incidents Reported on the Shariati – Attar OHL due icing

Failure Date	Duration of power outage [hh:mm]
February 26, 2011	3:40
February 28, 2011	6:07

3.1. CLIMATIC DATA AND ACCUMULATION MODELS

Galloping requires moderate to strong wind at an angle greater than about 45° to the line, a deposit of ice or rime upon the conductor lending it suitable aerodynamic characteristics, and positioning of that ice deposit (angle of attack) such as to favor aerodynamic instability.
The ice, wet snow or rime deposit has to have strong adhesion to the conductor. Accumulation of snow in the pilot line has been shown in Figure1.
The influences of the climatic data including precipitation types, amount of precipitation, temperatures, dew point temperature, and barometric pressure, were entered into the model of snow and ice accumulation.
Actual ice accumulation may vary greatly over short distances due to spatial variations in precipitation type, wind speed, and temperature. Therefore, using the climate data and the Accumulation model to determine the thickness of ice on the conductors would only be an estimated of the actual amount of ice in one specified location. Figure 2 shows average number of days with snow and average number of days with temperatures below -4ºC during a year in Mashhad city between 1960 to 2005.

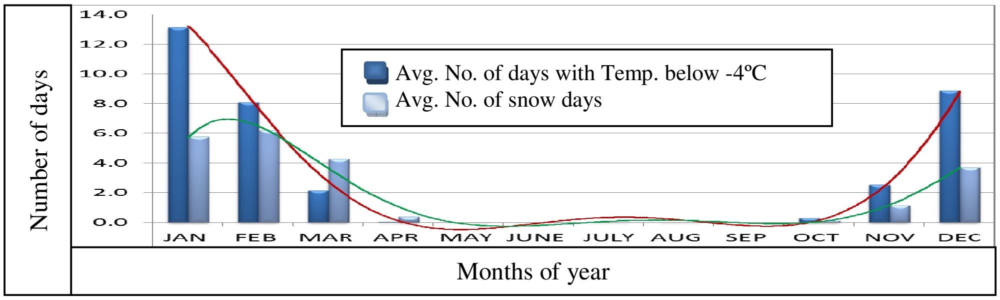

Figure 2. Climatic data in Mashhad City between 1960 to 2005

3.2. ANALYSIS OF OPERATIONAL RECORDS AND TECHNICA SPECIFICATION FOR EXISTING TRANSMISSION LINE

Although the OHL designers consider the effect of loading cases and climate conditions in Designing transmission power lines and therefore, they expect maintaining performance reliability of power line in its lifetime, because of the passage a long time and changing meteorological conditions or consequences of OHL underdesign in some of OHLs, it seems necessary to rechecking the designing factors that can lead to redesigning with considering update factors and using approaches for increasing the reliability of power transmission lines.

To investigate this matter in pilot project, the operational records and existing meteorological conditions in terms of loading zone in which the pilot line is located, was analyzed.

The results of investigations showed that designing of this OHL considering heavy loading zone has been done, however, due to cross the OHL of the mountainous region between tower 115 to tower 125 and affected by the strong winds in this section, Heavy ice or wet snow accretion on phase conductors of overhead lines, has been lead to major service outages.

4. NOVEL APPROACHES TO REDUCE GALLOPING EFFECTS

In ELECTRA [Cigre, 2000b].[1] The various control approaches were classified as “retrofit” or “design” systems. The ELECTRA paper also includes a list of discontinued methods. This paper will focus on control devices which are considered to be practical, and in use, at least on a trial basis, on operating lines. Using a case study shows a novel approach of a hybrid solution using interphase spacers and counter weights to overcome galloping failure and increasing the reliability of transmission line.

On the 115 kV, 230 kV, and 500 kV lines built since the 1970’s [2], the earliest rigid spacers were assembled from ceramic insulator sections joined with an aluminum tube, and attached to the conductors using standard suspension clamps. These spacers were heavy and difficult to handle and install. Some early rigid spacers suffered breakage of the insulating sections due to the high compressive forces occurring during galloping. There were also failures of the welded joints at the ends of the central aluminum tube. Later, polymeric insulators were substituted for the ceramic sections, creating a lighter and more manageable, but still rigid, assembly. To increase the performance of interphase spacer, flexible clamps were also used in both end of it.

Also, in order to avoid of corona effect, it is necessary to use middle fittings for flexible interphases with smooth edge.

Our field investigation and study determined critical zones and areas in the pilot line, for which we proposed the hybrid solution using two type of flexible interphase spacer 3.8m and rigid interphase spacer 4.9m length as shown in Figure 4 and counter weight as shown in Figure 5.

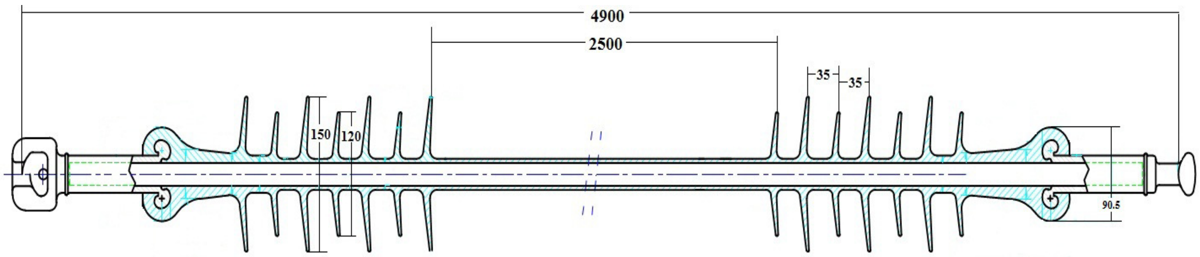

Figure 4. Interphase spacer for 132 kV Lines

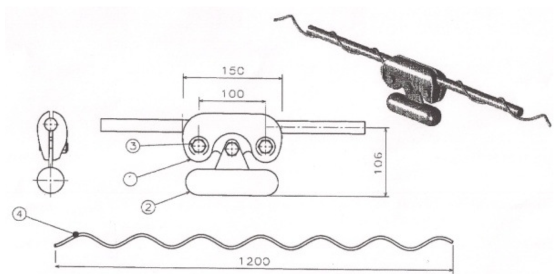

Figure 5. Counter weight damper

5. MODELING AND DETERMINATION OF THE EXACT RANGE OF FAULT

In order to model the power line in PLSCADD software, some input data were needed. Due to a lack of OHL design data after more than 40 years of operation and to achieve practical results, necessary information to be gathered from the field included: structure list data, route in terms of longitudinal profiles according to GIS data.

The weather information obtained from a 45 year survey, the region climatic conditions, and towers information according to their arrangement was entered in PLSCADD software and galloping conditions were analyzed. Tower 115 to tower 125 have operational records, showed a critical section in this line, as mention in 3.2.Therefore,in order to model the critical zone, by the special analysis part of PLSCADD software, sections between towers 110 to 130 were simulated. Figure 6 shows a picture of section 110-111 which has been affected by galloping and this matter has been approved by operational records.

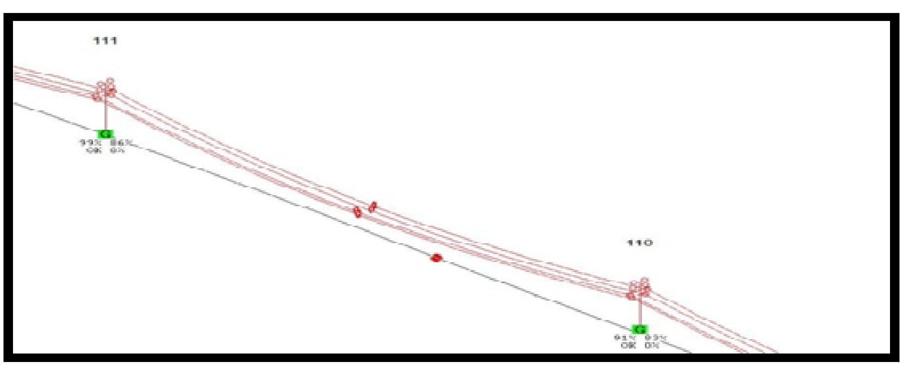

Figure 6. A sample of the galloping analysis in the critical zone between towers 110 to 111.

Analysis results indicated that in strong wind cases, 15 spans have galloping problems in this critical zone. The precise modeling and analysis of the shield wire implied the absence of any galloping problems in the spans of this critical zone.

6. STATUS OF OVERHEAD LINE AFTER IMPLIMENTATION OF NOVEL APPROACH

By applying the proposed measures and implementation of the solution plan, the problems were significantly reduced. An example of the modeling results and the galloping behavior after implementation of solution plan are shown in Figure 7.

Using the proposed approach and installation of both recommended interphase spacers and counterweight have significant effect of reduce galloping problem in the pilot project and no outage and line failure has been reported after 6 years.

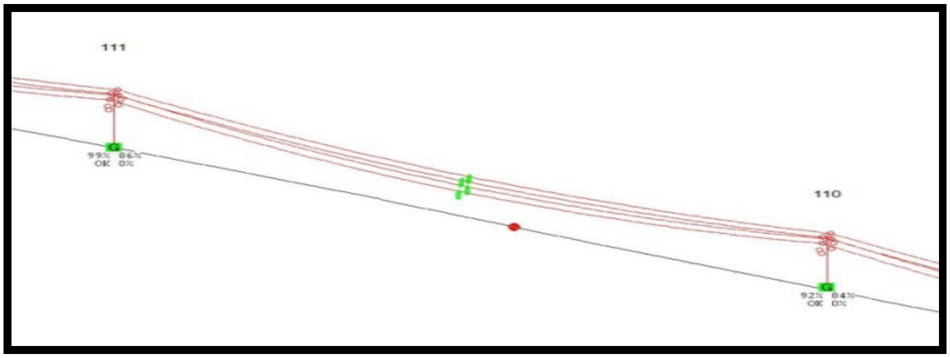

Figure 7. Simulated status of pilot project using novel solution

7. CONCLUSION

In summary, the interphase spacers and counter weights have a good track record for eliminating flashovers during galloping but they do not prevent the galloping motions. Although merely reduces the amplitude but still galloping motions still exist.The side effects of galloping such as high loads on the support structures and damage to the conductors at the suspension clamps can still be a problem with interphase spacers and hybrid solution using counterweight and interphase spacer could be a practical and novel approach for increasing the reliability of transmission line in galloping condition.

Observations in the field show that motion still occurs with interphase spacers in place, especially when the galloping conditions are such that high levels of motion can occur. The side effects of galloping such as high loads on the support structures and damage to the conductors at the suspension clamps can still be a problem with interphase spacers. Interphase spacers are also subject to damage if they are not designed for the dynamic loads applied to them. In this study, galloping problems were significantly reduced on the pilot transmission line through the use of counter weights and an interphase spacer design with flexible end fittings to limit the motion of the conductor. s. According to economic evaluations, the proposed solution has economic justification, so that its return on investment period is 2.5 years and the profitability coefficient is 4.3. No line failure and outage has been reported for 6 years.

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