BBAA VI International Colloquium on:
Bluff Bodies Aerodynamics & Applications
Milano, Italy, July, 20-24 2008

DISPLACEMENT PROBABILITY DISTRIBUTION IN THE CASE OF GALLOPING OF CONDUCTORS COVERED WITH A D SECTION ON A HIGH-VOLTAGE OVERHEAD TEST LINE

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Keywords: Galloping, conductor vibrations, probability distribution, transmission line.

ABSTRACT

This paper deals with one aspect of an extensive research study on the galloping that occurs in the case of a high-voltage overhead test line located in a natural site: the probability distribution of the displacement amplitudes of its conductors. The test line consists of three suspension spans and two dead-end spans. A D-section jacketing was added to the conductors in the middle span to induce galloping amplitudes typical of those encountered as ice is formed on the conductor. Conductor displacement was monitored using two accelerometers on each conductor and two video cameras. Different factors potentially influencing galloping amplitude, such as the mode that is excited, conductor tension and D-section mass per unit length have been also examined. The results show that the probability distribution of the galloping amplitudes of single conductors follows that of a Gaussian one.

1 INTRODUCTION

One of the main concerns regarding conductor galloping are the large displacements induced by the phenomenon and the risk to bring transmission line conductors close together and cause flashovers. In some cases, conductor damages can even result from wires melting due to the resulting arc and/or abrasion due to collisions. Although galloping has been studied for many years from a theoretical and experimental points of view [3], few remedies have been developed to prevent its onset. In order to examine the phenomenon more closely, a new study was undertaken at IREQ's test line site in collaboration with TransÉnergie, Hydro-Québec's transmission division. To induce galloping amplitudes typical of those encountered as ice is formed on the conductor, a D-section jacketing was added to the conductor. While the "aerodynamic" closeness of the D-section to an average ice accretion section may be questionable, it should be noted that there is no such average section and that the conductor response may vary greatly for different ice sections. However, the D-section was well known to induce high galloping amplitudes [1] [3]. Some of the data described here have been covered in previous publications [7] [8], where the data analysis technique used to calculate conductor amplitude was described and one of the main findings was that wind azimuth may strongly influence galloping amplitude.

This paper deals with the results obtained on single conductor strung at different tensions. The internal lay-out of the D-section jacketing allowed for the insertion of addition weight without displacing the center of gravity of the conductor: two different values of the mass per unit length were then used on the conductors. It is well known that a small amount of ice deposit is required to induce galloping on conductors. However, since the first author observed galloping with an estimated ice accretion of 2.3 kg/m on single conductors and 8.3 kg/m on quad bundles during the January 1998 ice storm in the South Montreal area (Quebec, Canada), there was concern about the dynamic loads associated with such masses during galloping. Consequently, D-sections with mass per unit lengths of 1 and 3 kg/m were used to study those effects.

The results and conclusion will be preceded by a description of the experimental setup.

2 DESCRIPTION OF TEST LINE

The tests were carried out at Hydro-Québec’s test line in Varennes, which consists of three suspension spans and two dead-end spans (Fig. 1 and 2). The site, built on agricultural land, is exposed to a low turbulent wind regime conducive to severe wind-induced conductor galloping, and is oriented perpendicular to the predominant wind direction. The test line comprises different testing positions for horizontal arrangements of conductors as well as tower arms allowing for a vertical arrangement of conductors.

The tests were performed on single Condor conductors suspended with I-insulator strings. The conductor has an outside diameter of 27.8 mm, a mass per unit length of 1.522 kg/m, a rated tensile strength (RTS) of 127 kN and is made of 54 aluminium strands over seven steel strands.

D-sections, which are generally assumed to produce severe galloping, were used to induce conductor galloping without being dependent on the temperature and precipitations (Fig. 3). As mentioned earlier, the center of gravity of the D-section and the conductor were coincident. The

Test and phase		Mechanical tension of the conductor (kN)	Conductor plus D-section mass per unit length (kg/m)
1	A	52.0	2.52
	B	46.4	
	C	35.6	
2	A	70.2	4.47
	B	63.4	
	C	51.9	

Table 1: Description of test configurations

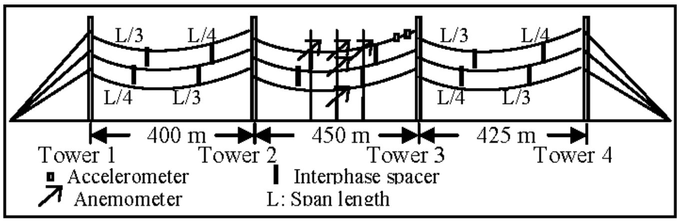

Figure 1: Line setup with interphase spacers

Figure 2: Test line

sections were attached to each conductor in the middle span only. Their height was 75 mm. Their mass per unit length is provided in Table 1 as well as the conductors mechanical tension with the D-sections.

Conductor displacement was monitored using two piezo-resistive accelerometers on each conductor and two video cameras. The wind speed, yaw and elevation angles were monitored by means of four bivane-type Gill anemometers located at conductor height (Fig. 1). A fifth anemometer of the same type was located at mid-span at a height of 10 m.

Figure 3: D-section

3 RESULTS

As already mentioned, repeated flashovers during galloping is one of the main utilities' concern since they don't want to interrupt their customers' alimentation. Consequently, many statistical studies have already been conducted based on visual observations during conductor galloping on transmission lines [2] [4] [5] [6] [9] to derive semi-empirical formulas in order to predict maximum galloping amplitudes of transmission lines. Quasi-continuous measurements taken at the test line allow us to perform a statistical analysis and determine the probability distribution curve of conductor galloping. The peak-to-peak amplitude of every galloping cycle was determined at the position along the span where galloping amplitude was maximum. An example of such a distribution curve is show in Fig. 4.

The experimental distribution of galloping amplitude was determined using the following approach:

$$d\left(n\frac{\Delta Y}{\sigma}\right)=\frac{\sigma}{\Delta Y}\frac{N_n}{N} \quad (1)$$

Where

N : Total number of galloping cycles ;

N_n : Number of galloping cycles with a peak-to-peak amplitude in the range $n\,\Delta Y \pm \Delta Y/2$;

n : Number of intervals which results in the amplitude when multiplied by ΔY ;

ΔY : Resolution of galloping cycle amplitude chosen equal to 1 peak-to-peak ;

σ : Standard deviation of the amplitude.

A Gaussian distribution was superimposed on the data and the fit with the data is good.

The standard deviation of each test is shown in Table 2 as well as the maximum galloping displacement during the test over the standard deviation. It appears that three times the standard deviation which theoretically includes 99.7% of the data would include all the results obtained except for test 1A.

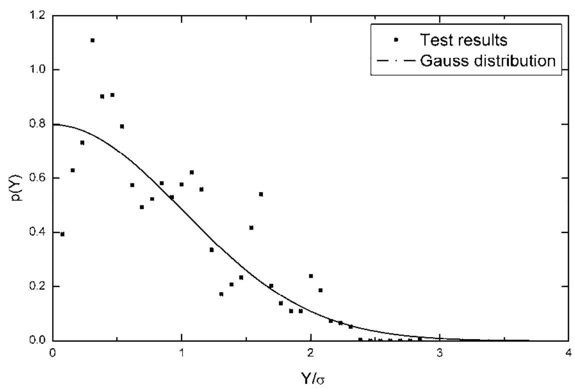

Figure 4: Predominant modes (1C: T=36 kN, m=2.5 kg/m)

Test and phase		Standard deviation of the normalized displacement σ (peak-to-peak)	Maximum displacement over standard deviation Y_{max}/σ
1	A	8.8	3.6
	B	8.4	2.9
	C	13.0	2.8
2	A	14.6	2.9
	B	15.2	2.6
	C	17.5	2.6

Table 2: Distribution of normalized amplitudes

4 CONCLUSION

It has been shown that the galloping displacements follow a Gauss distribution. Consequently, the properties of the Gauss distribution may be used to evaluate the probability that galloping displacement will be above given amplitudes. It may also be used to evaluate the probability that two phases will remain above given distances.

More details are also given in the full paper regarding the effect of wind velocity variations on galloping amplitude variations as well as modes excited as galloping builds up on a line.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the participation of Jean-Louis Leblanc, Réal Therrien and Pierre Guilbault for the test setup as well as George Desrochers, Marc Charbonneau, Robert Dansereau, Dave Bouchard (all of them being from Hydro-Québec and TransÉnergie), and Jean-Marc Payer (from Hélix Uniformé) for discussions during the project.

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