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TECHNICAL BROCHURE
TF B2.11.06

State of the art of conductor galloping

Executive summary

Galloping is a low frequency, high amplitude wind induced vibration of both single and bundle conductors, with a single or a few loops of standing waves per span. Frequencies can range from 0.1 to 1 Hz and amplitudes from ± 0.1 to ± 1 times the sag of the *span*. In the case of distribution lines, amplitudes of up to 4 times the *sag* can occur. Galloping is generally caused by a moderately strong, steady crosswind acting upon an asymmetrically iced conductor surface. Galloping is usually observed with limited amounts of ice but there have been some examples of non-ice galloping. The large amplitudes are generally but not always, in a vertical plane whilst frequencies are dependent on the type of line construction and the oscillation mode excited. Winds approximately normal to the line with a speed above a few m/s are usually required and it cannot be assumed that there is necessarily an upper wind speed limit.

Galloping has a major impact on the design of overhead lines, for both clearances and tower loadings, as large load variations may occur between phases and even between each side of a given tower, causing horizontal and vertical bending as well as torsional loads on towers and crossarms. Due to the large amplitudes, breaking bending loads may be reached at conductor attachment points and tower bolt failures have been observed. Wear also results at some locations (e.g. - yoke plates and insulator pins), which may only become evident with severe consequences much later, possibly during other seasons.

Torsional motion of the earthwire or phase conductors (single or bundle) may occur with very significant amplitudes. In the case of bundles, collapse may occur causing problems at suspension arrangements.

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Types of Motion

Galloping takes the basic form of standing waves and traveling waves, or a combination of the two. The standing waves may occur with one or up to as many as ten loops in a span. Small numbers of loops predominate.

Observed peak-to-peak amplitudes of galloping are often as great as the sag in the span and are sometimes greater, especially in short spans. Amplitudes approaching the sag in magnitude have been observed with as many as three loops in the span but beyond that number, the amplitudes become smaller.

The predominant conductor motions in galloping are vertical but there is often a horizontal component of motion transverse to the line. The vertical and horizontal motions are often out of phase, so that a point on the conductor near the mid-loop traces an elliptical orbit.

When galloping occurs with one loop in the span, there may be significant longitudinal movement of the conductor (in the direction of the line). Peak-to-peak swings of the order of $^1/_2$ meter have been observed. These motions are most noticeable in longer spans.

Twisting motion of single conductors during galloping is difficult to discern from the ground, ● ● ●

but it has been detected and measured by the attachment of suitable targets to the span. Peak-to-peak rotations greater than 100° have been observed and the torsional movement during the galloping limit cycle (the elliptical orbit) has the same frequency as the vertical motion, although it is generally out of phase with it.

Damage and Other Consequences

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, crossarms 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.

Dynamic shock loading occurs when a steep-fronted galloping wave is reflected at a tower. Repeated reflections can cause vibration damper weights to 'droop' and in extreme cases, damper messenger cables to break, dropping the damper weights.

Dynamic loads have also caused loosening of crossarm and bracing bolts in tower structures and loosening of wood poles in the ground. Jumpers at deadend towers have been thrown up onto crossarms.

When galloping amplitudes are great enough to permit flashover between phases or from phase to ground, arcing damage to conductor surfaces results. The damage has been significant enough in some cases to cause broken strands in conductors and to result in complete failure of earthwires or even phase conductors.

Forced outages caused by galloping result in loss of revenue and sometimes in other costs associated with re-establishing service. These consequences are generally considered to be more severe than direct damage to lines.

Amplitudes

For single conductors, the curve defining the maximum amplitude over conductor diameter, is given by:

$$\frac{A_{pk-pk}}{d} = 80 \ln \frac{8f}{50d} \qquad (1.1)$$

where A the peak-to-peak amplitude (m), d the (sub)conductor diameter (m) and f the sag of the unloaded span (m) at 0°C.

For bundle conductors, limited to observations of galloping with wind speed up to 10 m/s:

$$\frac{A_{pk-pk}}{d} = 170 \ln \frac{8f}{500d} \qquad (1.2)$$

Design load

- Anchoring level: tension load extremes during galloping can range from 0 to 2.2 times the static value (with ice but no wind). Nevertheless, ice loads during the most severe galloping are generally very limited so that, in absence of particular data, static value to consider can be evaluated at 0°C without ice load.
- Suspension level: vertical load extremes during galloping can range from 0 to 2 times the static value

Protection Methods

There are three main classes of countermeasure employed against galloping:

- Removal of ice or preventing its formation on conductors.
- Interfering with the galloping mechanisms to prevent galloping from building up or from attaining high amplitudes.
- Making lines tolerant of galloping through ruggedness in design, provision of increased phase

clearances or controlling the mode of galloping with interphase ties.

An overview of existing techniques is given as follows:

NO	DEVICE NAME	APPL'N	WEATHER CONDITION		LINE CONSTRUCTION			COMMENTS
			Glaze	Wet snow	Dist'n	Single trans'n	Bundle	
1	Rigid Interphase Spacer	Widely used	Yes	Yes	Yes	Yes	Yes	Prevents flashovers, reduced galloping motions
2	Flexible InterphaseSpacer	Widely used	Yes	Yes	Yes	Yes	Yes	Prevents flashovers, reduced galloping motions
3	Air Flow Spoiler	Widely used	Yes		Yes	Yes	Yes	Covers 25% of span Limited by voltage. Extensive field evaluation
4	Eccentric Weights & Rotating Clamp Spacers	Used in Japan	No	Yes	No	Yes	Yes	Three per single span. One per spacer per subconductor
5	AR Twister	Used in USA	Yes		Yes	Yes	Yes	Two per span
6	AR Windamper	Used in USA	Yes		Yes	Yes	Yes	Two per span
7	Aerodynamic Galloping Controller (AGC)				Yes	Yes		Number based on analysis
8	Torsional Control Device (TCD)	Used in Japan		Yes	No		Yes	Two per span
9	Galloping Control Device (GCD)	Used in Japan		Yes	No		Yes	Two per span
10	Detuning Pendulum	Widely used	Yes		Yes	Yes	Yes	3 or 4 per span. Uses armor rods if tension is high. Most extensive field evaluations
11	Torsional Damper and Detuner (TDD)	Experim ental	Yes	Yes	No	No	Yes	2 or 3 per span