AR Products
Solutions for Galloping and Vibration Control

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On Galloping | Bundled Conductors

There are few technical studies of bundled conductor galloping.

- 2005 | CIGRE Working Group – State of the Art Survey on Spacers and Spacer Dampers. Companion to CIGRE Reports on State of the Art of Conductor Galloping (1995, 2005, 2007)
- 1995 | CIGRE Field Observations on galloping
- AIM Study Day on Galloping by Bundled Conductors | Univ of Liege, Belgium | 10 March 1989
- CIGRE International Symposium on Galloping | Paris, France | 1990

Galloping is low frequency motion that can occur without ice. Galloping starts once a sustained wind, within a very narrow band of wind angle of attack, reaches a critical wind speed (10-15mph.) Bundled conductors gallop at steady wind speeds of 10-35 mph. Twisting the conductor helps dump off aerodynamic lift. Conductor twisting helps raise the critical wind speed at which galloping amplitude starts (to 20-25mph).

Galloping occurs in conditions where ice, snow, and/or wind creates aerodynamic instability at certain velocities and when wind blows in certain directions. Galloping affects single-conductor and bundled-conductor transmission lines.

- Shorter Spans <700 ft. have two points of instability; at the 25% and 33% span points.
- Instability at low wind speeds (10mph) is caused by torsion motion.
- Factors influencing galloping: spans of consistently the same length, flat terrain, steady wind force at the “angle of attack” (45° to the conductor), and ice accretion (on the windward side)
- Twisting mechanisms are recognized in the industry as effective at controlling galloping.
- Ground wires rarely gallop because of small diameter and relative density (6000 vs 3000 for ACSR conductor)

Factors influencing galloping of bundled conductors:

- Frequency drives galloping[1].
    - Natural frequencies: 1st mode (1/3Hz), 2nd mode (2/3Hz), 3rd mode (1Hz),
    - Conductor stiffness (tension) and inertia determine the natural frequencies.
    - Twisting natural frequency and vertical galloping natural frequency is roughly the same; a coupling occurs between the twisting motion of the sub conductors and the vertical galloping motion. Torsion motion leads vertical motion in phase.
- Steady turbulence and wind gusts have greater impact on bundled galloping than on single conductor motion.
- Torsion stiffness is many times greater in bundled conductors than single conductors[2].
- Aeolian vibration of bundled conductors exceed that of single conductor spans by up to 5 times[3].

Galloping by Bundled Conductors

- CIGRE reports there is a direct influence of design of suspension and anchoring dead-end arrangements on the torsional characteristics of the bundle and on the occurrence of vertical/torsional flutter type galloping[4].
- Mean peak-to-peak galloping amplitude of bundled is .64x sag; peak amplitudes can reach greater than 1 x sag[5].
- Ice accretion forms at 90° of the windward sub conductor. Because the bundle is not free to rotate, the ice foil is not symmetrical. In icing/sleet conditions, the ice is D- or triangle shaped. These accretions covering only 90° of the windward sub conductor causes a windward wake oscillation on the leeward sub conductor[6].

- Tests in Japan showed ice shapes (D or triangle shaped) affected galloping motion and amplitude[7]. Observations included variation in dynamic tension along the span, peak galloping amplitudes reached .75 of sag and large-amplitude, figure eightshaped galloping.
- Bundled spans are more easily influenced by adjacent spans (higher tension, coupled frequencies, restrained sub conductors)
- Single and double loop galloping can occur in the same span.
- 1st mode galloping (at low wind speeds ~10 mph) of this coupling motion is not easily detected.

The Challenge of controlling galloping in bundled conductors. Studies (by individuals and the work groups of CIGRE) have found 3 effective means to control galloping: twisting the conductor (as little as 10% twist will change the 45°angle of attack by the wind), using eccentric weights and drag dampers that use aerodynamic lift.

- Studies have shown that unrestrained sub conductors will twist independently, dumping off aerodynamic lift and reduce galloping motion[8]. Rigid spacers separate the bundles yet restrict this free-range torsional motion <u>and</u> increase the torsional stiffness of the bundled conductors.
- Coupling of natural frequency of bundled conductors with galloping frequency (1 Hz) makes the bundled conductor susceptible to 1st mode gallop at all span lengths.
- 1st mode galloping is determined by wind speed (<10 mph) and even if full peak galloping amplitude is not realized (gallop up 75% of sag and down 40% of sag), coupling (torsional and galloping) motion creates stress in lateral and longitudinal directions.
- Sub conductors having restricted torsional motion (joined by rigid spacers) cause increased oscillation of the bundle.
- Tests have shown that the torsional stiffness of bundled conductors increases when the conductors are covered with ice[9], exposing the span to rolling and bundle collapse.
- Experience has shown that shorter spans may not achieve peak galloping amplitudes of 1st mode galloping, but the higher tension of shorter conductors and the increased torsional stiffness of the bundles leads to more oscillation and higher frequency vibration. This *fatigue oscillation* (torsional and longitudinal) leads to increased wear on the hardware, structures and system[10].

References & Technical Papers on Dynamics of Bundled Conductors

1. Richardson, AS, Martuccelli, JR and Price, WS (1963) *Research Study on galloping of electric power transmission lines," Paper 7*, 1st Symposium on Wind Effects on Buildings and Structures, Teddington, England. This study funded by the Edison Electric Institute, studied the phenomenon of galloping conductors on overhead transmission lines. The research included computer analysis, wind tunnel testing, testing a scale model of a 3 span/3 phase transmission line in the Wind Tunnel at MIT Aeroelastic Laboratory and field tests. Both single conductor and bundled conductor spans were tested for galloping motion. The study proved the underlying Den Hartog theory of galloping and established under what conditions of wind speed and ice shape conductor galloping will occur.
2. Richardson, AS. *Mechanical & Electrical Properties of Large Bundled Conductors*, ESMO/IEEE, 1995 Columbus, OH
3. Richardson, AS *Vibration of Bundled and Single Conductors: A Comparative Cast Study*," Electric Power Systems Research, 1990.
4. CIGRE. *State of the Art of Conductor Galloping*. Work Group (2005, 2007)
5. Jeff Wang, PhD. IEEE *Workshop on Galloping*. 2018
6. Richardson, AS. *Designing Quad Bundles Against Galloping*, AIM Study Day on Galloping of Bundled Conductors, Univ of Liege, 10 March 1989
7. CIGRE 1995. *Field observations on galloping*
8. Richardson, AS. *Predicting Galloping Amplitudes*, ASCE Journal Engineering Mechanics, 1988
9. Leppers, P.H and Rienstra, S.W. *Investigations on Galloping*, AIM Study Day on Galloping of Bundled Conductors, Univ of Liege, 10 March 1989

10. Richardson, AS, Dubois, Herve, Lilien, Jean-Louis, *Predicting galloping fatigue in quad bundles*, CIGRE Proceedings of Symposium 28 August 1990

Additional Resources

CIGRE – State of the Art Conductor Galloping | 2005, 2007
CIGRE – State of the Art Survey on Spacers and Spacer Dampers | 2005
CIGRE – Field observations of overhead line galloping | 1995
Montefiore Electric Institute, Liege University Belgium - *On Galloping* | 1989

Lilien, JL and Havard, D., CIGRE Task Force presentation B2.11.06
Richardson, AS *Predicting Galloping Amplitude I, II, III, IV.* 1988

