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Wet snow accretion on overhead lines with French report of experience

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ABSTRACT

This article deals with the accretion mechanisms of wet snow observed both on a stranded conductor sample in wind tunnel conditions and on real power lines in natural weather conditions. It summarizes the theory and practical observations. Report of experience from France are given in order to demonstrate the efficiency of this passive preventive method based on the increase of torsional stiffness of conductors and to introduce wet snow risk map and countermeasures in France.

1. Morphological description of wet snow

Wet snow is the usual result of the rapid metamorphosis of dry snowflakes formed at negative air temperature into supercooled clouds, when the snowfall passes through the 0 °C isotherm and penetrates into an atmospheric air layer at positive temperature.

The dry snowflakes consist of a jumble of millimetric hexagonal ice crystals collected under a weak mechanical bonding up to reach a centimetric dimension. On reaching a slightly positive temperature, the snowflakes slowly begin their metamorphosis by rounding their crystalline shape. The metamorphosis sharply accelerates when, on impact an aerial obstacle, the snowflakes are fully exposed to the air–snow thermal exchanges. Then, a superficial liquid phase occurs over the ice, the hexagonal multi-crystals of snow round out, shorten, and turn into agglomerates of sub-millimetric ice granules, weltering in their own melting water, and surrounded by trapped air bubbles (Fig. 1).

This metamorphosis transforms the previously weak mechanical bonding of dry snowflakes into a new strong capillary bonding of wet snow granules, as described by Wakahama (1965) and theorized under the name of "grain clusters" by Colbeck (1973, 1979).

The wet snow material presents a large range of its three components – ice granules, liquid water and air bubbles – according to the heat exchanges at the air–snow interface. For example, if the heat exchanges are restricted (low wind speed <1 m s^{-1}, air temperature close to 0.1 °C, high snowfall intensity >10 mm h^{-1}), the wet snow material presents a low consistency of half-transformed snow (density <100 kg m^{-3} due to low wind pressure), a low liquid water content (LWC <5%) and a lot of air bubbles (more than 70% in volume). Conversely, if the heat exchanges become very active (wind speed # 10 m s^{-1}, air temperature # 2 °C, low snowfall intensity <2 mm h^{-1}), the wet snow material contains a fully transformed snow of hard consistency (density # 500 kg m^{-3} due to high wind pressure), a high liquid water content (LWC >40%) and few air-bubbles (less than 40% in volume).

This metamorphosis is clearly located between 0 °C and 2.5 °C (Admirat and Grenier, 1984; Dalle, 1984). When the air temperature becomes excessive (>3 °C), the wet snow agglomerates turn into water droplets.

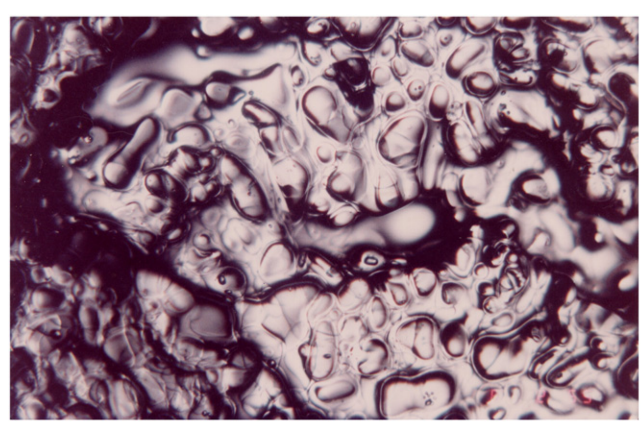

Fig. 1. Typical agglomerate of wet snow material, seen under microscope, consisting of ice granules (# 100 μm), capillary liquid water (5 to 15%) and air bubbles (often >50% in volume), strongly joined together by capillary forces.

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2. Weather conditions

From a meteorological point of view the altitude of the 0 °C isotherm is a determining factor. Because wet snow only occurs between 0 °C and 2 °C, the wet snow zone of all wintry precipitations, affects an atmospheric air layer of only 300–400 m deep, located just underneath the 0 °C isotherm altitude. In this typical zone the wet snow adheres to all aerial obstacles with strong capillary bonding. At lower altitude, therefore at warmer air temperature, the LWC of wet snow agglomerates increases up to 100% and the wet snow precipitation turns into a rain precipitation.

Wet snow events of low intensity happen with usual winter atmospheric disturbances. They last 3–5 h, with precipitation intensities lower than 2–5 mm h^{-1} water-equivalent (less than 10–15 cm of snow depth on the ground). They produce snow sleeves of less than 5–8 cm in diameter and less than 1 kg m^{-1} in snow overload, causing no or little damage to overhead lines.

The more important events occur with uncommon stormy weather conditions during the winter season. They last more than 10 h with precipitation intensities sometimes greater than 10 mm h^{-1} water equivalent (up to 50–70 cm of snow depth on the ground). They produce snow sleeves greater than 20–30 cm in diameter and up to 5–10 kg m^{-1} in snow overload, which exceeds the usual mechanical resistance of electrical equipment, conductors or supports. Such events cause the heaviest damages to overhead lines, possibly increased by strong windy conditions.

3. Two snow accretion mechanisms according to torsional stiffness of the conductor

During a ten year period, many observations of accreted snow mechanisms have been well documented in France for both 20 kV and 150 kV overhead lines (Fig. 2).

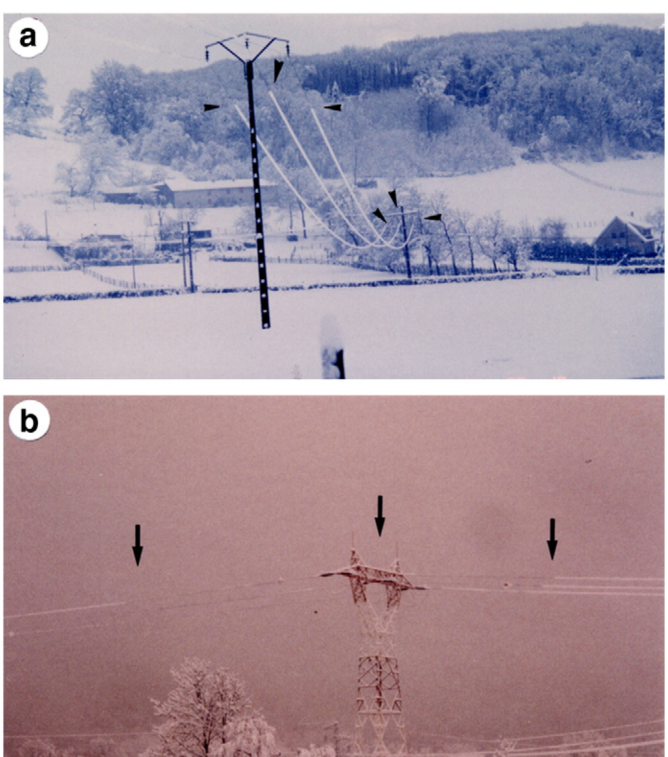

Fig. 2. Usual observations of the two accretion mechanisms on overhead lines: axial accretion of 10–20 m in length, on each part of the anchoring points and cylindrical accretion beyond this distance (a) on a 20 kV line and (b) on a 150 kV line.

They show cylindrical snow sleeves formed along the major length of the spans, while simple snow deposits are formed on a short length on each part of the anchoring points (Admirat and Dalle, 1984). The observed scenario is as follows: at the beginning of the wet snow event, the accreted snow forms a deposit on the overall length of the windward side of the span.

Some hours later, a very homogenous cylindrical snow sleeve is formed all along the span, excepted at its two extremities, on each part of the anchoring system, where a simple, more or less fragmented, snow deposit is observed on the windward side of the conductor, while the leeward side of the conductor is left bare (Lapeyre and Admirat, 1986).

These observations suggest therefore two different accretion mechanisms in relation to the torsional stiffness of the span: a cylindrical accretion mechanism, wherever the torsional stiffness is low, making the conductor rotation possible, and an axial accretion mechanism wherever the torsional stiffness is high, making the conductor rotation impossible (Fig. 3).

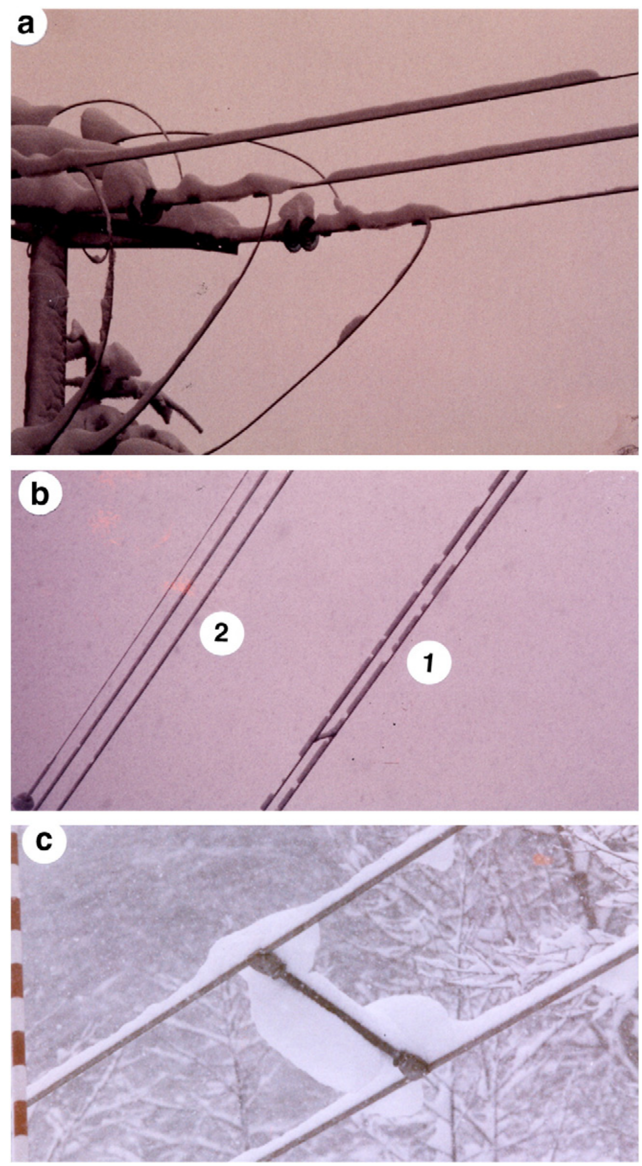

Fig. 3. Three detailed examples of the accretion mechanism and torsional stiffness of the spans: (a) axial accretion close to the anchoring point on a 20 kV distribution line, (b1 and c) fragmented axial accretion on each part of the spacer on a 500 kV transmission line, (b2) cylindrical accretion on the length of low rigidity, without spacer.