REDUCTION OF VIBRATIONS OF OVERHEAD TRANSMISSION LINE CONDUCTORS CAUSED BY WIND POWER PLANTS

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ABSTRACT

Without damping measures the bending strains in the conductor wires caused by aeolian vibrations will exceed the allowed limits recommended by CIGRE and IEEE, so that conductor damages probably could occur. The results of the energy balance calculation show that the vibration intensity could reduced by means of damping so that the lifetime of conductors no more depends on the distance between wind power plant and overhead transmission lines (OHTL) and so the probability of conductor damages would not be increased by erection of wind power plants. The installation of spacer dampers for the conductor bundle and vibration dampers for the earth wire is recommended.

1. WIND POWER PLANTS AND OVERHEAD TRANSMISSION LINES

Aeolian vibrations mostly occur at steady wind velocities from 1 to 7 m/s. With increasing wind turbulences the wind power input to the conductor will decreased. The intensity to induce vibrations depends on several parameters such as type of conductors and clamps, tension, span length, topography in the surrounding, hight and direction of the line as well as the frequency of occurrence of the vibration induced wind streams.

The dynamic behaviour of an overhead line in the wake of the rotor of a wind power plant was part of a scientific analysis investigated by the Institute for Electrical plants and Energy management of the Technical University Aachen [1].

In the wake of wind power plants (up to 3 x diameter of the rotor behind the plant) the wind velocity will be reduced up to 0,5 of the velocity of the free wind stream, so that lower wind velocities could be expected more frequently here. That's why the probability of a higher stresses for the conductors caused by wind-induced vibrations will be greater than without wind power plants [2].

On the other hand the intensity of turbulences will increase which will hinder the arising of vibrations.

The both important parameters for inducing vibrations, wind velocity and turbulence intensity, depend on the distance to the rotor and the hight of it.

The investigations showed an increasing of damage probability on OHTL due to the wake of wind power plants of the factor 2,5 to 3,5 between one and three rotor diameters behind the plant which will cause an equivalent decreasing of lifetime of conductors and earth wires.

That's why they recommend damping measures which prevent that the lifetime of conductors will depend still more from the distance to the wind power plant. Based on this knowledge the Committee K 421 „Overhead Transmission Lines“ of the German Electrotechnical Commission in the DIN (German Institute for Normalization) and the VDE (Association of German Engineers) issued recommendations for minimum horizontal distances between wind power plants and OHTL [3]:

- overhead lines without damping:
    - the distance has to be $\geq$ 3 x rotor diameter D
      (measured from the top of the rotor blade)
- overhead lines with damping:
    - the distance has to be $\geq$ 1 x rotor diameter D
      (measured from the top of the rotor blade)

These rules were implemented into Czech legislation with effect from 4.9.2009. Due to the fact that the stream conditions in the wake will advance vibrations on the one hand and will obstruct them on the other hand but the local correlation could only be measured insufficiently, the present consideration proceed on the assumption of advancing stream conditions (laminar wind flow of 1– 7 m/s). Thus, the calculations are on the safe side.

The standard DIN EN 50341-3-4 allows to do it also without damping measurements if it can be proved that the line is situated outside of the wake (e.g. at very high wind power plants and if the minimum distance between the top of the rotor blade in the most disadvantageous position and the outermost reposing conductor is > D.

2. VIBRATION DAMPING

The knowledge of the mechanical self damping of conductors is an important parameter for the energy balance calculation. The impedance and the efficiency of the vibration damper (Fig. 1) have been measured in relationship to frequency and used as input data for the energy balance.

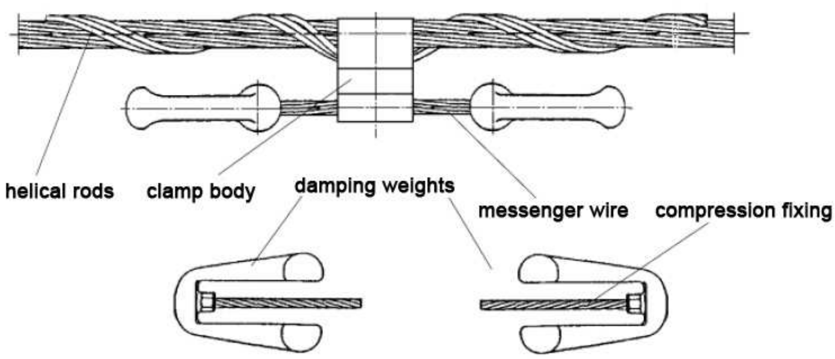

Fig. 1: Vibration damper

To investigate vibrations on conductors, earth wires and optical ground wires (OPGW) with and without dampers engineers use computation programs which make it possible to calculate the vibration stresses practice oriented within the limits of given input data and boundary conditions.

The used model for determination of fatigue loading of conductors is based on the balance between conductor self damping and wind input energy, called energy balance principle.

The method takes the following conditions in consideration:

- Wind conditions (turbulence, velocity)
- Terrain factors
- Type of conductor
- Pension load
- Conductor self damping
- Damper characteristics

The wind input energy and the dissipated energy in conductor and dampers are compared for all expected frequencies. For a profound description of the method see also the ETZ-report No. 15 [5].

The calculation method is successfully used for many years. The efficiency of the derived damping measurements could be proved by means of optoelectronic measuring device on several lines and important river crossings i.e. the Elbe-crossing.

Aeolian vibrations could cause fatigue damages on conductors, cables or dampers by the time. To prevent this, the stresses shall not exceed limits as specified.

At conductors and earth wires the bending stress can be compared with the fatigue limits for lifetime recommended by CIGRE and IEEE. If exceeding these values damages could occur.

The velocity of the damper clamp shall be remain under the limit of 10 cm/s. The vibration dampers are tested at this vibrating velocity in an endurance test. They must stand at least 100 million vibrations without damages. If the velocity of the damper clamp remains beneath the value of 10 cm/s the bending stresses remain in the endurance range so that damages could not be expected.

Bundled conductors (for example: triple bundle 400 mm) with rigid spacers installed cannot be damped with vibration dampers. It is recommended replace them by spacer dampers (Fig. 2).

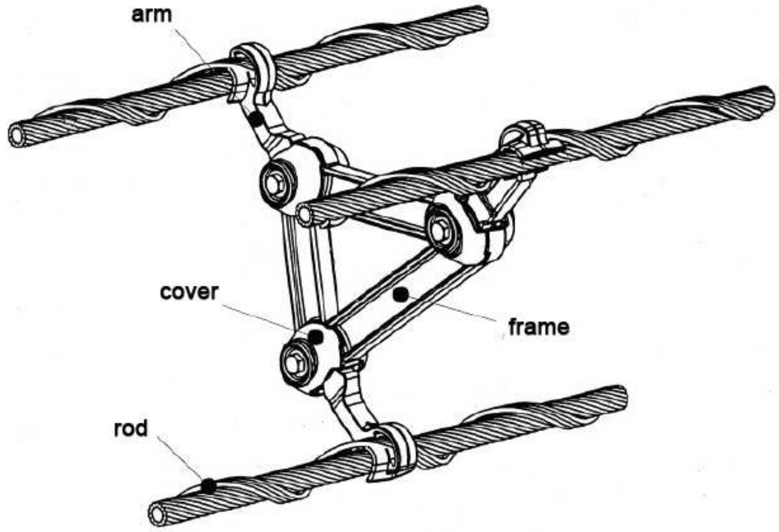

Fig. 2: Spacer damper – with silicone rubber elements for triple bundle conductors

The damping efficiency of the provided spacer dampers had been tested and proved many times in practice. Several thousands pieces of this type are in use for many years, also in the Czech Republic.

The calculations yield the bending strains in the aluminium wires of the conductors, the vibration angles, the amplitudes and the bending strains in the free span as well as the clamp velocity and the absorption coefficient for the vibration dampers.

The computations of the bending strain yield information about the fatigue loading of the conductor compared to the international accepted limit of 150 μm/m. Additionally, the computations of clamp velocity shows the dynamic loading of the damper compared with the limit value v = 10 cm/s for the amplitude of velocity.

Obviously, the allowed bending strain will be exceeded significantly without damping measurements so that the damping of the spans is recommended. The computation shows clearly that the bending strain could be taken securely beneath the limit if installing two vibration dampers.

3. CONCLUSION

The results of the energy balance calculation prove that the vibration intensity of conductors can be reduced by means of suitable damping (installation of spacer dampers resp. 2 dampers per span) so that no vibration damages caused by nearby wind power plants could be expected.

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