Abstract

The lightning protection standards describe how wind turbine blades should be protected to LPL1 (200kA) stroke from the tip and down to radius 20m, whereas only a few evidences of such exposure has been presented. Both numerical simulations as well as extensive field data provide evidence that the direct strike exposure is focused on the tip of the blade, and that the peak current of strokes expected inboard are of limited amplitude. This has led to the Lightning Zoning Concept for blades, as well as a revised approach of the Exposure Risk assessment which is treated in the present paper.

In 2010 a zoning concept for lightning protection of wind turbine blades was published, refined slightly in 2012. The Zoning concept was developed to present an engineering tool for assessing which lightning strikes to that the different regions of the blade. In the present paper, this Zoning concept is revised based on more recent analysis and field investigations, and defines regions of the blade that would be exposed to certain peak currents.

Attachment process

Direct lightning attachment to any structure can be triggered by processes initially formed at the cloud, or by the development of an upward leader at the grounded structure. These important processes are the basis for deciding where the lightning will strike the turbines, downward strikes may attach several different places depending on the origin of the DW leader and the charge distribution along the leader, whereas upward strikes tends to be triggered at the extreme points (blade tips).

Revised Zoning Concept

After the first suggestion of the Zoning Concept, lightning protection systems on blades exceeding 80m lengths have been designed. By conducting the detailed attachment point distribution analysis on such longer blades, it was found that smaller amplitude strikes may attach further inboard on the blades. The process involved the use of numerical models of downward leader propagation and the following inception of upward leaders from the structures proposed by Becerra [7], to determine which parts of the wind turbine are exposed to direct attachment of different amplitudes. The equations outlined in the papers by the Uppsalas lightning research team has been implemented in Comsol and Matlab, to enable import of a 3D turbine geometry and analyzing the exposure [5].

The principle using inclined leaders with prospective peak currents of 3-20kA has been applied on a generic turbine structure with 60m blades. On Fig. 4, the percentages of strikes attaching to each blade radius (averaged over all three blades for different rotor angles) is plotted for different prospective current peaks. Note that the peak of the scale is set to 3%, meaning that the actual fraction of strikes attaching to the tip region for strikes of higher amplitudes cannot be seen. The results indicate clearly that for higher current amplitudes, the attachment tends to move towards the blade tip.

Realising that the 3ka or 5kA strikes may attack further inboard on the blade, changed the original Zoning concept in [8] where strikes only could attach at the blades outer 20m. The revised concept shown on Fig. 3 includes a Zoning concept enabling direct strikes of 10kA for the entire blade length.

The consequence of extending the direct strike zone and using the Zoning Concept for blade LPS design, is then that the inboard sections should also be capable of withstanding direct strikes of 10kA. This may be achieved quite simply for blades with CFC in the shells, which can then be designed to accommodate the direct strikes, but for GFRP blades, the likely hood of a puncture through the root section must be addressed.

Conclusions

The paper addresses a need for an engineering tool useful for LPS designers and still accounting for the slightly more complex lightning exposure experienced on large wind turbines.

The revised Zoning Concept provided along with the short guideline to achieve proper LPS designs for different blade types, will ensure that lightning engineers focus the attention towards the areas of the blades where lightning exposure is highest. After the first suggestion of the Zoning Concept, lightning protection systems on blades exceeding 80m lengths has been designed. By conducting the detailed attachment point distribution analysis on such longer blades, it was found that smaller amplitude strikes may attach further inboard on the blades. The process involved the use of numerical models of downward leader propagation and the following inception of upward leaders from the structures proposed by Becerra [7], to determine which parts of the wind turbine are exposed to direct attachment of different amplitudes. The equations outlined in the papers by the Uppsalas lightning research team has been implemented in Comsol and Matlab, to enable import of a 3D turbine geometry and analyzing the exposure [5].

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The revised zoning concept currently used is seen on Fig. 5. Location of the lightning discharge (in percentage) in damaged blades with mixed fiberglass and carbon fibre structure

References

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K. Bertelsen, H. V. Erichsen and S. F. Madsen: ‘New high current test principle for wind turbine blades simulating the exposure to the root end of the blade, exposed to direct attachment with current levels of only 10kA, 10/350us

Evaluating the risk may therefore lead to the decision that the protection according to strikes of lower amplitudes is unnecessary, because they only can come to the conclusion that protection according to strikes of such low amplitudes is unnecessary, because they only occur very rarely.