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Enhanced lightning effects testing for optimized wind turbine reliability

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Abstract

Lightning related damages and costs are regarded being one of the larger issues for wind turbine operators in certain regions of the world, and the effort in improving designs, manufacturing quality and scheduled maintenance of modern wind turbines has become very important for the manufacturers. Since 2010, wind turbines may have been certified according the IEC 61400-24 Wind turbines – Part 24: Lightning protection, requiring verification of the applied protection measures. The present paper presents a new mean of verification, namely full scale lightning current testing on complete nacelles and wind turbine blades.

The ELITE (**E**nhanced **LI**ghtning effects **TE**sting) project starts by investigating the actual lightning exposure of wind turbines by gathering information from many research communities, wind turbine manufacturers, owners and operators of the systems. This information is compiled into design and test requirements, which is the basis for the generator design. The generator is designed to inject lightning current pulses (IEC LPL1) into full scale structures like 50-100m blades and 3-10MW nacelles, to investigate the overall exposure and determine the compliance with the lightning protection standards.

Main Objectives of the ELITE project

The overall objective of the ELITE project is to develop and demonstrate a next generation lightning test system capable of handling high-performance tests of full size wind turbine components, including 5-10 MW nacelles and 60-100 m long blades. The wind power industry is very aware of the lightning related problems and of the need for improved testing capabilities.

- Systematic collection and analysis of data concerning lightning protection of wind turbines generated during the past ten years on universities, in the manufacturing industry, on the customer side and from the numerous research projects completed by lightning consultants.
- Design, construction and validation of an impulse current generator to comply with the lightning test requirements raised by the wind turbine industry and defined by the lightning environment identified. To accommodate the requirements to the test pulses set forward in terms of waveforms, amplitudes, energies, etc., this process will require several engineering disciplines. Apart from High Voltage engineering and research into new means of storing and releasing the extremely large quantities of energy, the mechanical design must also ensure safe and reliable operation. The complex system requires a thorough understanding of all processes and involved techniques, and here the research team at DTU along with the experienced engineers at GLPS will work closely together. The generator design and construction will, upon completion, enable wind turbine and blade manufacturers to get the necessary verification tests performed also for future even larger structures.
- Demonstration of the newly developed test system on large full test setup, nacelle, complete wind turbine blade, etc.

The achieved experiences from previous testing on large-scale systems (see Figure 1 and Figure 2) with high- but not full level lightning impacts, will lead to new approaches for defining test and verification requirements, and thereby assisting manufacturers in increasing the documented reliability of wind turbines.

By pushing state of the art testing to a higher level, including requirements for certification and industrial standards, the entire industry will be driven in a cost effective direction making wind power even more competitive.

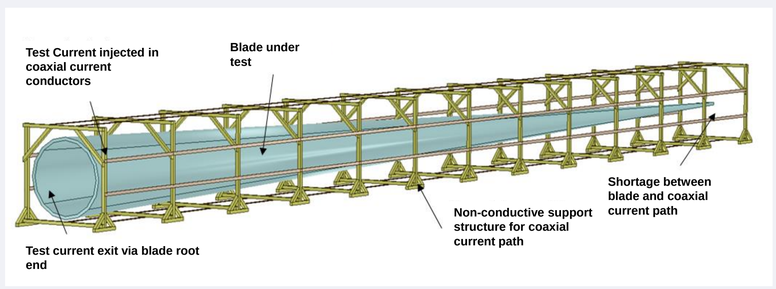


Figure 1: High current test in a full length blade test specimen

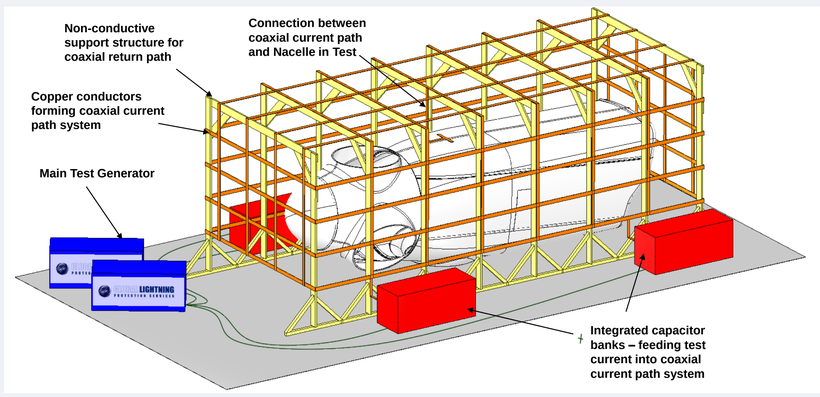


Figure 2: Full scale lightning test of large wind turbine nacelle, illustrating main test generator (blue containers), the coaxial current path system and additional integrated capacitor banks (red containers)

Lightning Parameter Study

A comprehensive lightning parameter study was carried out by the ELITE project team starting with a general classification of lightning incidents.

Lightning strikes can be divided into three different types of lightning: Downward lightning, upward lightning and bipolar lightning. Each of this those are initiated by different mechanisms and inherit its own characteristic parameters. The origin of downward lightning starts in the cloud with a partial breakdown that forms a leader, whereas the field enhancement over a tall object is responsible for triggering upward lightning.

The likelihood of the inception of upward lightning increases with the height of the structure. Therefore, the effective height of the turbine is utilized as a key parameter for the upward/downward relation of a construction. Eriksson and Meal [7] proposed a relation between effective height of a turbine and the likelihood of upward lightning inception.

$$p_{UL} = 52.8*\ln(h)-230$$

This relation provides a good estimation of the percentage of upward lightning strikes and is illustrated in Figure 3. Structures having heights less than 100m are usually struck only by downward lightning and structures with heights greater than 500m are usually assumed to experience only upward inceptions. Nowadays, wind turbines are constructed with increasing total heights of above 200m. The trend from the industry to pursue this development is confirmed.

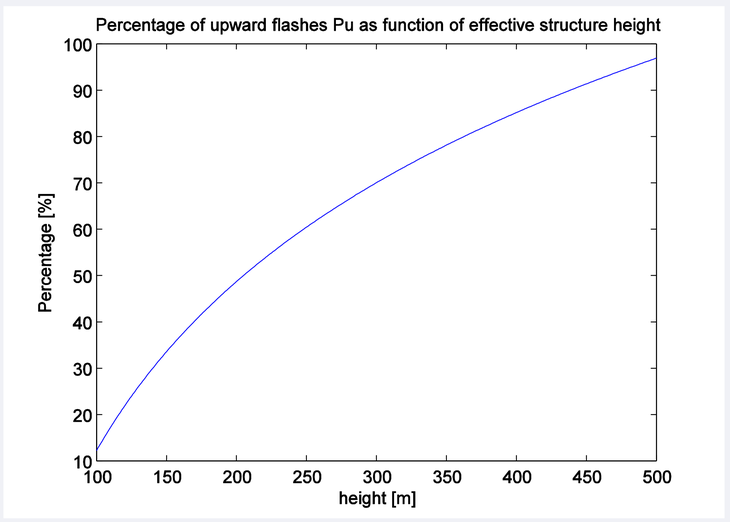


Figure 3 - Relation between upward flashes Pu as a function of effective height

A parameter study was carried out with the following sources of information:

- Lightning strike parameters recorded in wind turbines
- Lightning strike parameters recorded by lightning detection networks

Wind turbines are often the tallest objects in the surrounding environment. This protrusion is the trigger for upward lightning discharge that appears to happen more frequently than reported in the literature. It seems that upward lightning is triggered often before a downward lightning strike is formed in the cloud. The general design parameters given in IEC 61400-24, standard is representative for some locations, however, big differences were reported in global measurement campaigns and for winter lightning in Japan.

In general observations of lightning a low peak amplitudes but with high flash density is registered This observation is also consistent for offshore wind power plants.

The issue of winter lightning can be related frequent occurrence of upward lightning discharges.

A small fraction of these incidences lower huge amounts of charge to ground and requires special design considerations.

Peak current amplitudes are small compared to downward lightning incidences.

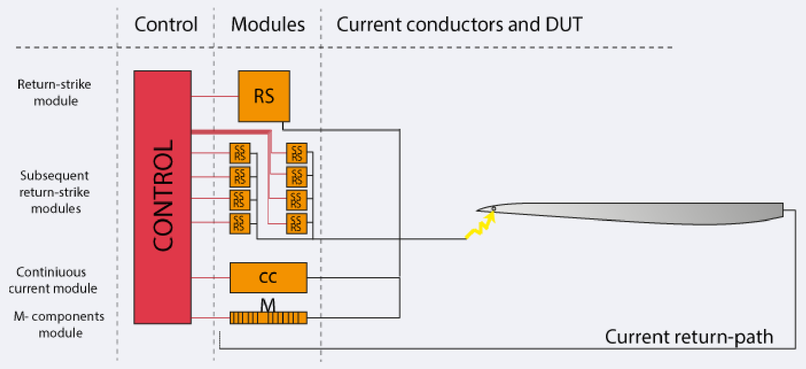
Requirements for New Test Generator System

By combining the results from the parameter study with requirements from the industry, the ELITE project is able to specify the requirements for future test systems in a 10 year horizon.

The new test system should be able to simulate the following lightning waveform parameters

- Postive and negative First Return Stroke: 10-200kA (10/350µs)
- Oscillating waveforme with the same values as for the First Return Stroke.
- Continuous current: 0.4-1.2kA
- Subsequent strokes and M-components: To be further considered

The test systems needs to be modulized as shown in Figure 4.



Conclusions

Lightning incidents on wind turbines are of growing concern since plants are getting larger and the consequence of a outage are becoming more critical. This poster addresses the process of developing a new test system for full scale lightning testing on large scale wind turbine components as blades and nacelles. The test system should be able to simulate lightning and to meet the testing requirements from the global wind industry for the next ten years.

The requirements for the new test system is based on a systematic data analysis revealing that the current test parameters, known form the IEC 61400-24 standard are still representative, but that the occurrence of strikes during the lifetime of the wind turbine needs to be considered carefully as well as testing needs to be performed on full size specimens, which requires special designed test equipment.

The new test system will be able to test with realistic waveforms on full size wind turbine components, including 5-10 MW nacelles and 60-100 m long blades.

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