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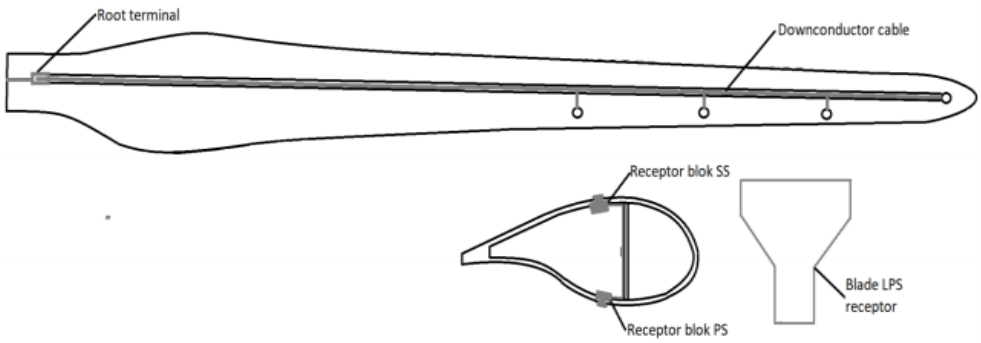
Lightning Protection Systems

Lightning damages to wind turbine blades account for a significant percentage of operational onshore wind claims. Based on more than 3,500 renewable losses, GRS' loss database indicates that lightning damage accounts for 60% of operational blade losses and almost 20% of operational wind losses overall. In our experience, we have found that the levels of damage observed can be highly variable – from repairable 'puncture' like damage, to the blade's destruction.

This white paper focuses on the blades' lightning protection system (LPS). We are often asked how these systems work and why severe blade damage can still occur. Here we will give an overview of how a typical LPS works and provide our *best practice* recommendations.

LPS Description

The LPS is a passive lightning protection system, ensuring that lightning strikes hitting the blade is transferred to the grounding. The systems are tested in accordance with the IEC 61400-24 standard. Dependent on the test tier, the system is designed to handle 100-200kA, without significant system wear. The diagram below shows a typical LPS:



Components

- **Receptors**. The receptor is a component made from metal, either copper or equivalent current transferring metal alloy. It is designed to attract lightning and transfer the load to the receptor block. The receptor is a replaceable component that is mounted post blade production. Risks of failure are worn receptor base or missing connection to the receptor block. Visual inspection can be used to determine a receptor's condition.

- **Receptor Block**. To connect the receptor with the down conductor cable, an aluminium block is cast into the blade with the down-conductor during blade production. A replacement requires a complex laminate repair as the blade laminate must be removed before the block can be accessed. Common issues involve detachment or missing connection to down conductor cable or receptor. A visual inspection cannot detect a lost connection between the receptor block and down conductor cable. Instead, it can be checked with a resistance measurement.

- **Down conductor cable**. The design of the cable varies between the different OEM's, including copper mesh, solid copper cable, linked aluminium plates and solid cable. The cable is centred on the web of the blade. It can be located on both LE or TE side dependent on the OEM design. Repair is possible but complex. Failure types include missing connection to root terminal, or receptor block and cable separation due to fatigue. Connection to the root

terminal can be checked with an internal visual inspection, which can be performed without entering the blade. Detecting separation of the down conductor cable is possible with a dedicated internal inspection.

- **Root connection**. The root connection is designed to transfer the load from the cable to the bypass system. Failure modes at the root terminal include missing connection to the down conductor cable. If no connection is established lightning would seek other paths to the ground, risking damages to the laminate or drivetrain, which is not designed to carry electrical current.

- **Lightning transfer system**. The design of the transfer system varies between the different OEMs. It can be spring coupling, brushing, or spark gap. These systems are designed to receive limited wear from lightning transfer; thus, they occasionally need replacement. A defect that can be observed in the lightning transfer system is insufficient contact in the case of the brush or coupling, or too large distance in the case of the spark gap. Visual inspection can detect such defect; moreover, for brush and coupling designs a resistance measurement can be performed.

Our Recommendations

Operators can reduce the risk of lightning damages by conducting regular scheduled LPS inspections. A maintenance strategy must be in place to define scope and inspection frequency. Receptor wear and sealant damages can be observed during a standard external inspection; down conductor connection to the root terminal can be visually inspected during planned turbine maintenance; the integrity of the down conductor can be examined during an internal blade inspection.

During an inspection, it is important to:

- Check the surface condition of the receptor. If material wear exceeds below the blade surface, a replacement is required.

- Check that the connection between the down conductor, root terminal and lightning transfer system is intact. If scorching and/or arching is detected near the root terminal, the connection is likely missing or partial.

- Check the surface condition of the transfer system. Too large spark gap or poor connection conditions could cause undesired lightning jumps to other parts of the turbine.

Major failures due to a lightning strike to the blade can be divided into two main categories:

1. A “force majeure” event is described as lightning with an unusually high current that exceeds the design limitations of the LPS.

2. A defect in the LPS leads to a reduced ability to transfer the lightning or a missing connection, thus reducing the likelihood of lightning travelling through it safely to the ground. The risk of the latter can be reduced by having a maintenance schedule in place for blades. This would also prevent some fatigue damages from going unnoticed.

While the “force majeure” damages are hard to influence, defects due to malfunctioning LPS can be minimised with a more focused effort from the industry. At present, Germany is the only country with meaningful legislation about the inspection of an LPS – it should be inspected every four years as a minimum. For comparison, turbine owners in Denmark are only obliged to inspect the LPS of their turbines when they have reached 20 years in operation.

Installing lightning trackers on sites can help to collect more parameters for lightning that are hitting the turbines. The wind industry will benefit from having easy access to accurate lightning data from the local site when assessing damage from lightning strikes.

Ultimately, from an insurance perspective, the breadth of cover commonly offered by a typical onshore wind policy regarding defects coupled with the difficulty in determining the strength of a lightning strike can make it challenging to apply any adjustments to the claim. However, the right expertise and experience of examining LPS and lightning damages can lead to

successful results in holding OEMs accountable for lightning damages which may be initially reported as “force majeure” events.