APPLICATION NOTE

Testing wind turbine lightning protection

How do wind turbines get damaged?

The most significant danger facing wind turbines is damage from lightning strikes (see figure 1). A German study found that 80% of wind turbine insurance claims paying out for damage compensation were caused by lightning strikes.

Figure 1: Lightning hitting wind turbines during a storm

85% of the downtime experienced by one commercial wind farm in the USA was found to be lightning related, costing around $250,000 in the first year of operation alone. And as another example, a large wind farm in the North Sea, near the German island of Helgoland, suffered such large losses because of lightning strikes that its operation was no longer cost effective.

Lightning faults cause more loss in wind turbine availability and production than the average fault. The number of failures due to lightning strikes is known to increase with tower height and a growing number of studies speculate that rotating wind turbines may be more susceptible to lightning strikes than stationary structures. Given that turbine heights are expected to increase and the renewable energy industry is growing, the number of failures is likely to grow with them.

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To reduce the likelihood of damage, protection from lightning is now being built into the turbines.

It is hoped that this will prevent the damage shown in figures 2, 3 and 4.

Figure 2: Turbine blade damaged by a lightning strike

Figure 3: Entry point at tip of turbine blade from a lightning strike

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Figure 4: Catastrophic failure of a wind turbine due to a lightning strike

How does wind turbine lightning protection work

The protection takes the form of a low resistance path to ground. The path goes from the blade's tip (figure 5) to the base of the turbine (figure 6). This path is shown in figure 7.

Figure 5: Blade tip

Figure 6: Turbine base

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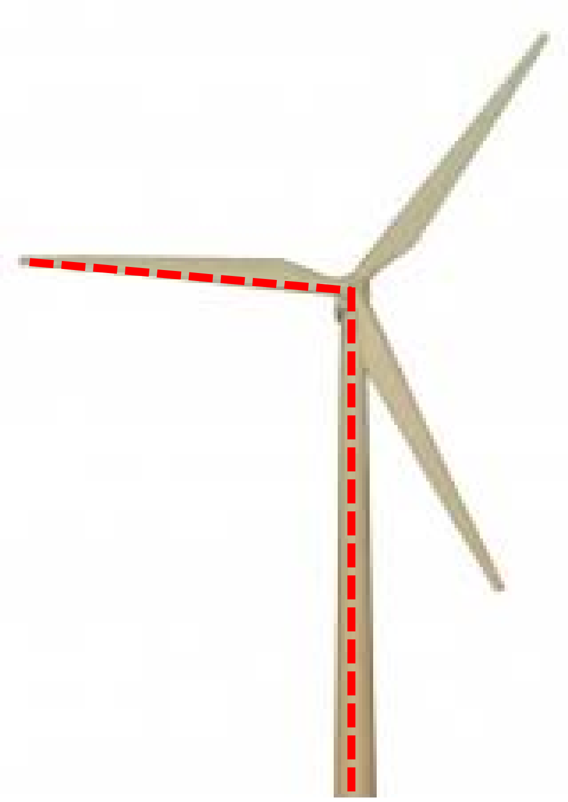

Figure 7: Low resistance path through turbine (indicated in red)

In the event of a lightning strike, current will flow to ground through the lightning protection system, not the sensitive equipment in the wind turbine. To ensure the protection will work when needed, the resistance of the path to ground should be measured at regular intervals, making sure it meets

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the limits specified by the turbine manufacturer (typically limited to 15-30 mΩ, depending on turbine size). For these tests, a low resistance ohmmeter should be used.

How to test wind turbine lightning protection?

The most important part to test is the conductor inside the blade. This measurement is taken between the blade's tip and the blade's root (see figure 8). This conductor is placed under significant strain as the blade flexes with the wind. Under strain, the conductor may fracture. Unfortunately, it is not enough to simply check continuity, because if the fractured conductor is touching at the break point during a continuity test, it will still pass. A current of 1 Ampere or more is recommended for this test.

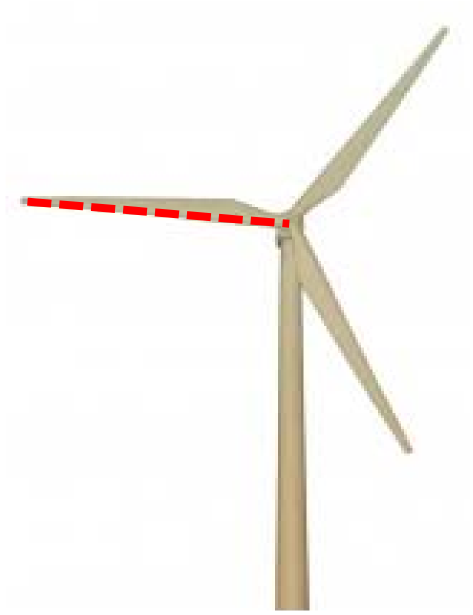

Figure 8: Lightning protection conductor inside wind turbine blade (in red)

When testing on the production line, the conductor inside the blade is tested on its own. The connection points are shown in figures 9 and 10.

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Figure 9: Connection at blade's root

Figure 10: Connection at blade's tip

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The length of a turbine blade can be seen in figure 11. The size of the turbines pose a problem, because low resistance ohmmeter test leads are typically very short. Due to the size of the wind turbines, some extra-long leads are required, often up to 100m.

Figure 11: Turbine blade laid down at ground level

This is a huge increase in length over standard test leads for low resistance ohmmeters. The long leads need to be designed with a low enough resistance to ensure that a measurement is still possible. To achieve this, an understanding of the test instrument design is important. Some instruments have a compensation factor to allow for power loss in standard test leads. When using long test leads, the compensation for power loss will no longer be sufficient. As a result, the test range of the instrument will be reduced.

When the resistance of the test leads is increased, the total value of R in the equation below will also increase.

$$\boldsymbol{P = I^2 R}$$

Where,

$R =$ *(resistance of load) + (resistance of test leads)*

$P =$ *output power of the test instrument*

$I =$ *output current of the test instrument*

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Since the maximum power output (P) of the test equipment cannot change, the rise in test lead resistance will cause the maximum current (I) to be reduced.

On the flip side, this principle can be used to your advantage in certain situations. If the load is inductive, it may help if more power is supplied to charge up the load. By reducing the length of the test leads, R will reduce. In this situation, it is P that will increase slightly, as there is a little more power in the instrument than is specified in the data sheet. This is intended to compensate for the losses in a few metres of test leads, but if the test leads are kept ultra short, this extra power is available for the load instead.

How can Megger help with testing wind turbines?

Megger, under its Ducter trademark, have has been developing low resistance ohmmeters since 1908. Recently, we have responded to this industry need by working alongside a leading wind turbine manufacturer to develop a kit for lightning protection testing.

As a result, we now have a range of KC test leads, developed specifically for use on wind turbines. When used with our DLRO10HD low resistance ohmmeter, the KC test leads complete the ideal kit for testing wind turbine lightning protection (see figure 12).

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Figure 12: DLRO10HD with a set of KC test leads

Benefits of the DLRO10HD and KC test leads:

- Heavy duty instrument case
- IP rating
- High power output
- Downloadable option (with DLRO10HDX)
- Up to 100 m long KC test leads