Improved lightning protection system enhances the reliability of multi-MW blades

John Korsgaard, Research Manager

LM Glasfiber

Lightning protection – 24 x 7 x 365

- 2000 thunder storms are active through out the world at any given moment producing approx. 100 flashes of lightning per second.
- In DK the average number of thunder storms is 10 per year
- Lightning releases currents of up to 200 KA released in a extremely short period of time.
- “Ordinary lightning” usually has a maximum stroke of approx. 30 kA

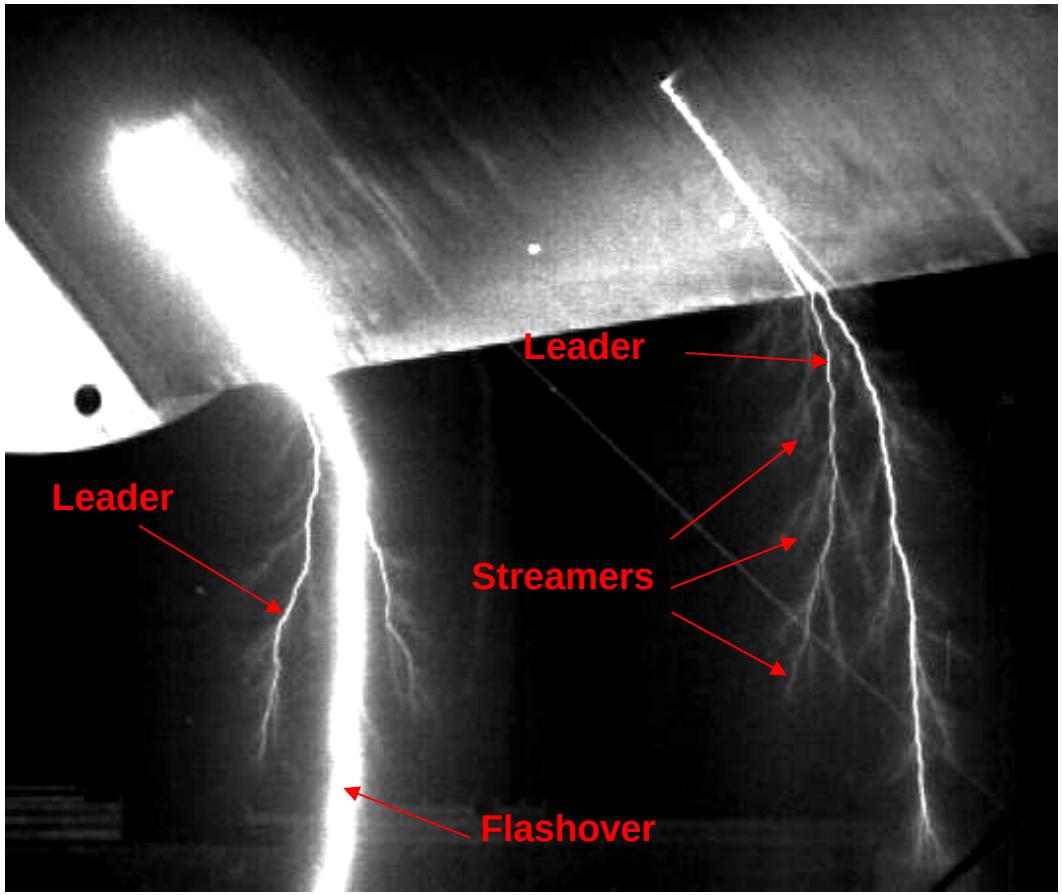
Lightning damage to blades

- Non-conducting blades without any conducting components are often struck by lightning and suffer major damage
- Statistics show that lightning causes 4 - 8 faults per 100 turbine years in northern Europe and up to 14 faults in southern Germany
- One third of the faults were caused by lightning strikes to turbines, the rest were due to power and telecommunications systems
- 7-10% of all lightning events involve wind turbine blades, which are the most expensive component to repair
- The above statistics cover a nine-year period from 1990 – 1998, mostly non lightning protected blades

Stages of a lightning event

Lightning events consist of a series of consecutive stages:

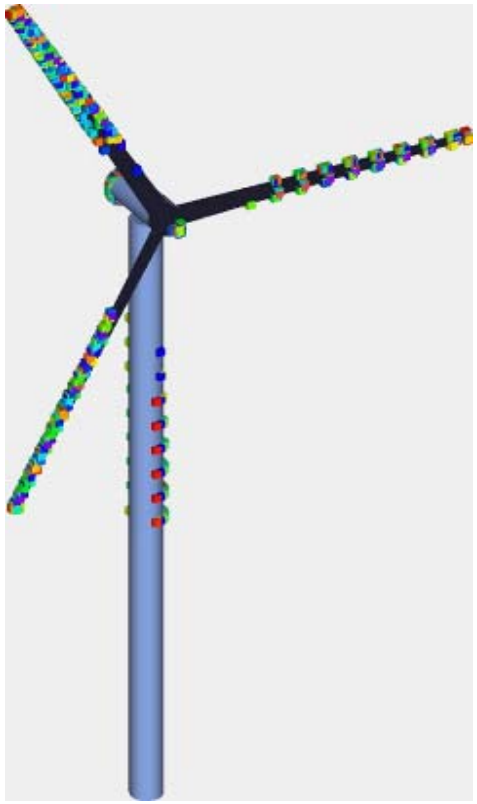
1. Initial corona forms
2. Streamers develop out of this initial corona
3. Leaders subsequently grow
4. Final jump occurs visible as the lightning flashover



Increased risk of inboard puncture for lightning strike of lower current

Lightning attachment points for the highest 2000 strikes <100kA

Lightning attachment points for the highest 2000 strikes <50kA



Lightning attachment points for the highest 2000 strikes <20kA

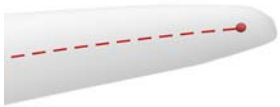
LM Lightning protection – continues improvements

Tip-end receptor I
1. First generation
2. Site test

1994

First lightning protection system introduced by LM on the global market

Tip receptor
1. Development based on experiences from version 1
2. Test MIL–STD-1757A
3. Mounted in more than 40,000 blades.



1995

Solution for smaller blades

Multi receptor I
1. Tested in 2002 after new SAE/EUROCAE standard
2. Norm IEC61024-1

2000

Solution for larger blades

Tip end receptor II, with drainage inside the end receptor
1.Tested in 2002 after SAE/EUROCAE standard
2. Norm IEC61024-1

2001

Solution for all blades

Blades with carbon fibers
1.Tested in 2002 after SAE/EUROCAE standard
2. Norm IEC61024-1

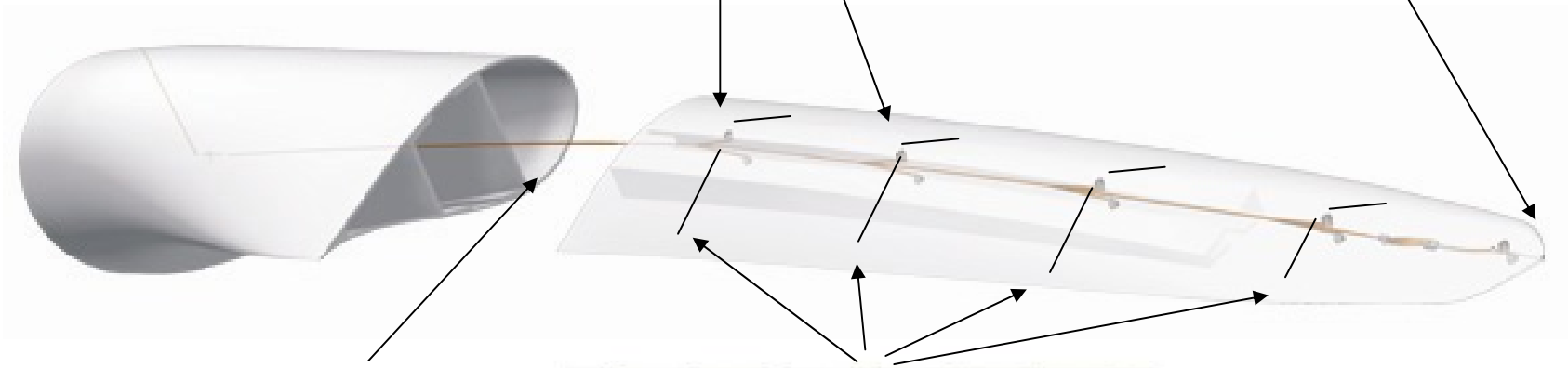
2003/4

Solution for blades with carbon fibers

LM Lightning protection for large rotor blades

Multi Receptors mounted on both sides of the blade

Drain Receptor

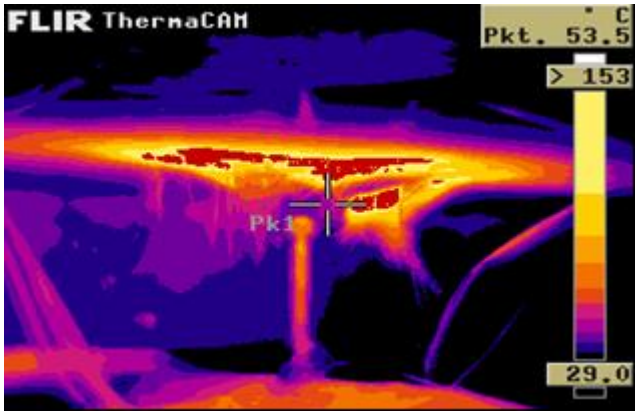


Conductive cable

Diverter Strips

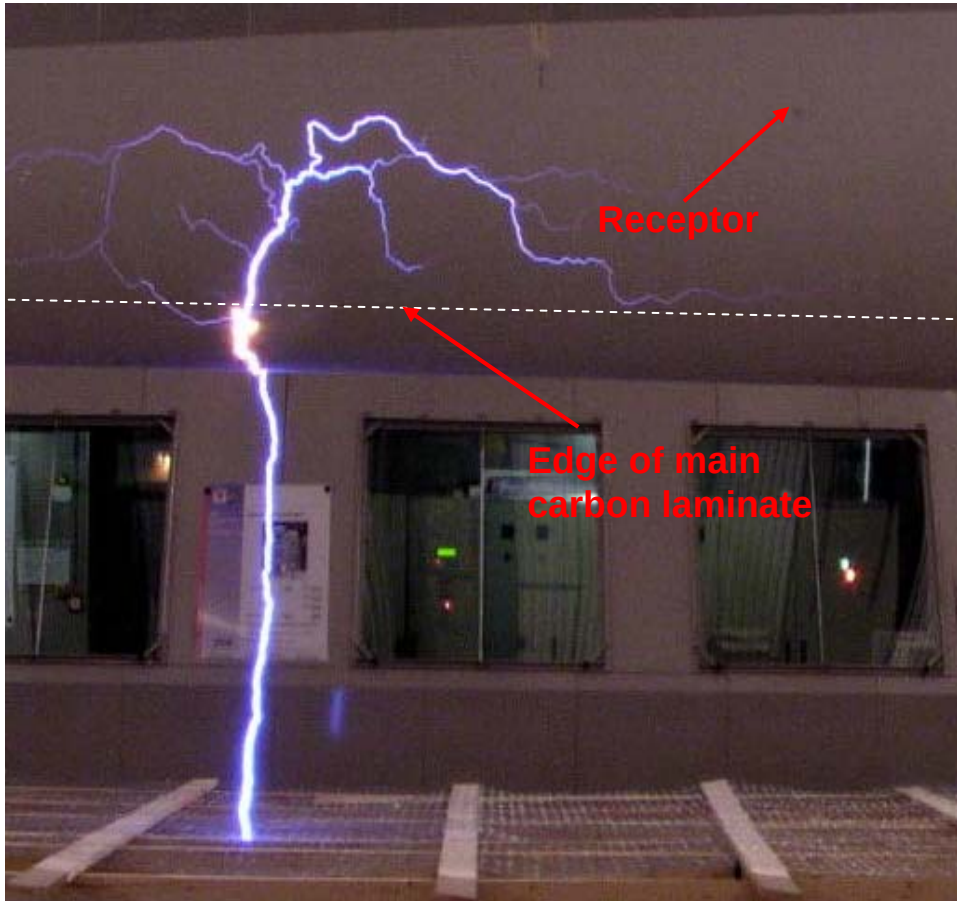
Lightning strike into an unprotected carbon laminate causes disastrous blade damage

- High Current impact tests (217 kA) show it is not sufficient to use carbon laminate lightning as down conductor
- Carbon fibre laminate is incapable of bearing the specific energy from a level 1 lightning strike (current = 200 kA, specific energy = 10 MJ/ohm) without resulting damage
- The inability of the carbon fibre laminate to distribute the lightning energy can lead to fire in the carbon fibre and subsequent deterioration of the carbon fibre laminate's strength



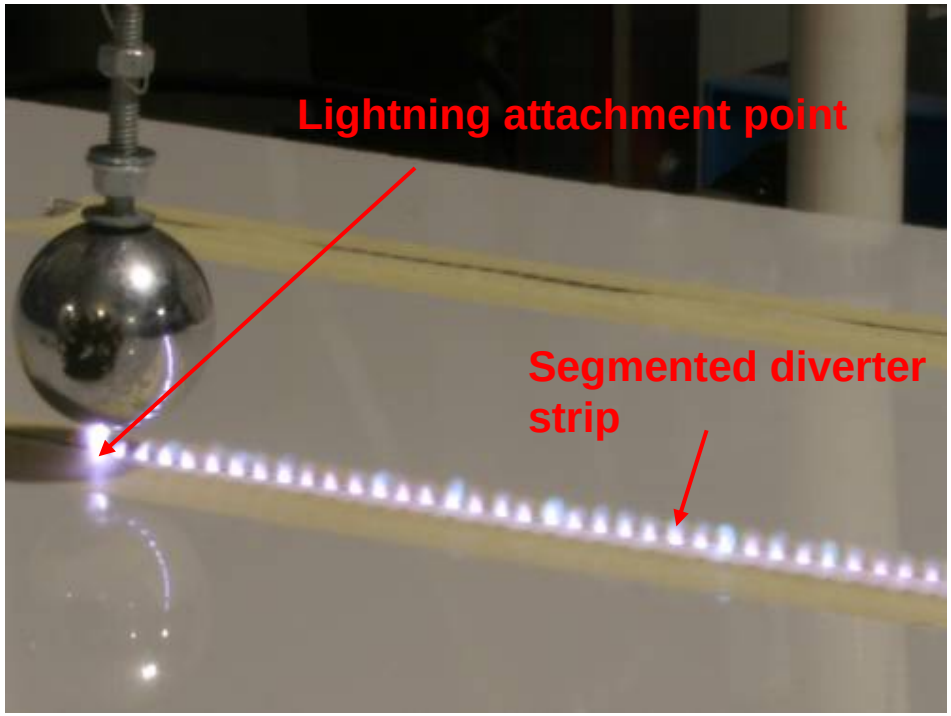
Unprotected carbon fibre leads to faulty strikes

- Extensive high-voltage impact tests show that the semi-conductive carbon fibre is struck by lightning just as frequently as the actual lightning receptors
- The challenge is to ensure rapid streamer and leader spread from those places on the blade where lightning strikes are intended to occur
- Even a medium-strength lightning strike that directly hits the carbon fibre laminate will result in extensive damage



The segmented diverter guides the flash to the receptor

- The high electrical field of lightning ionises the small air gaps in the segmented diverter, providing a conductive path for lightning leaders and flash current
- The maximum spacing between the segments in the diverter, and the minimum permissible spacing to underlying conductors (carbon laminate), depends on the voltage required to ionise the segmented strips
- The ionisation voltage must be much lower than that required to ionise a path along the bare surface of the blade or to puncture through the fibre glass insulation into the carbon laminate



1st prototype diverters did not pass the verification tests

The diverter before High Voltage test

The diverter during High Voltage test

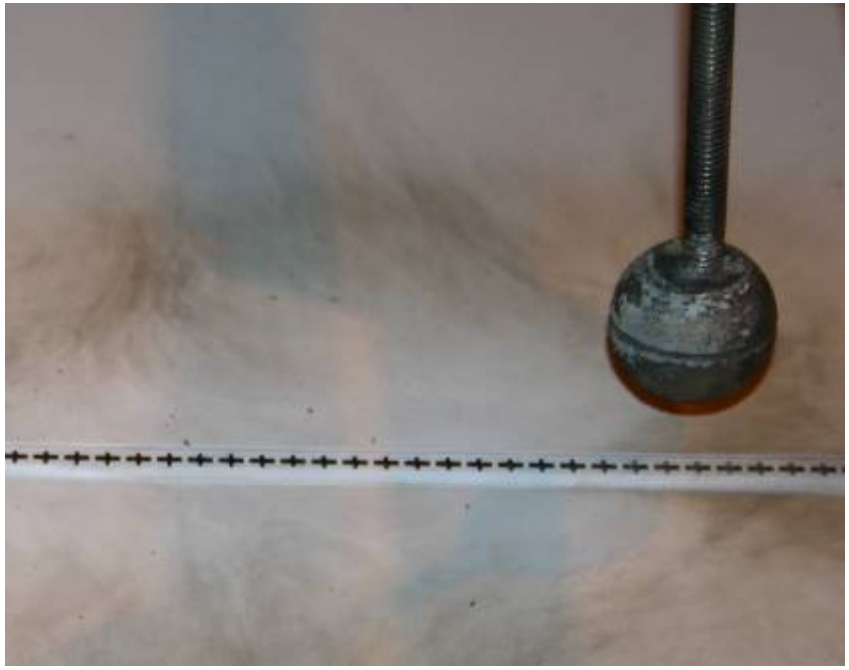
135kV AC rms

The diverter after High Voltage test

Bad result, burned off

LM designed a special diverter strip for use on rotor blades

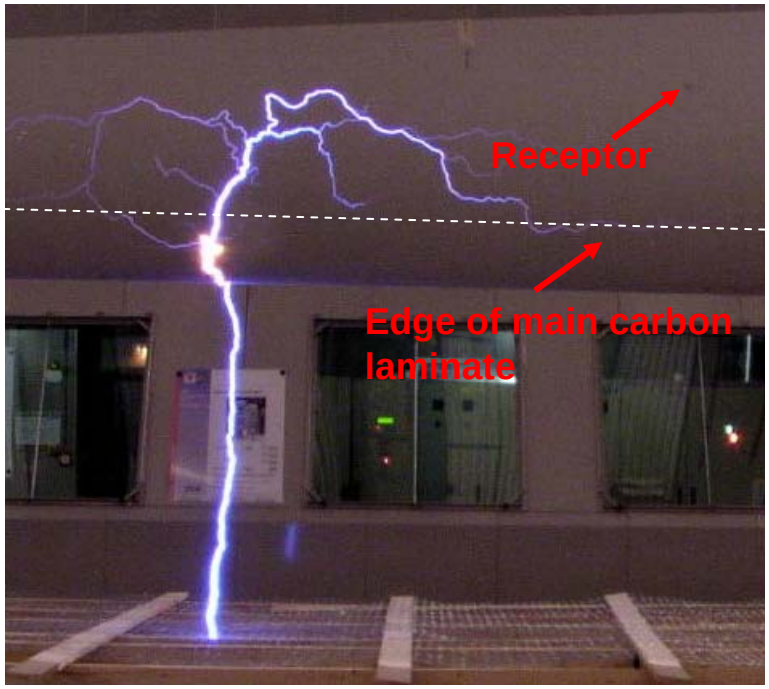
- Low maintenance. Designed to last for 20 years
- Low weight
- Easy to mount on the blade. Require no drilling holes
- Can be retrofitted
- Minimal influence on the air flow
- Current travelling in an ionised path above the segments of the LM DiverterStrip makes a smooth transfer to the receptor
- LM DiverterStrip withstands more lightning impacts compared with commercially available segmented diverters



LM DiverterStrip following high current test

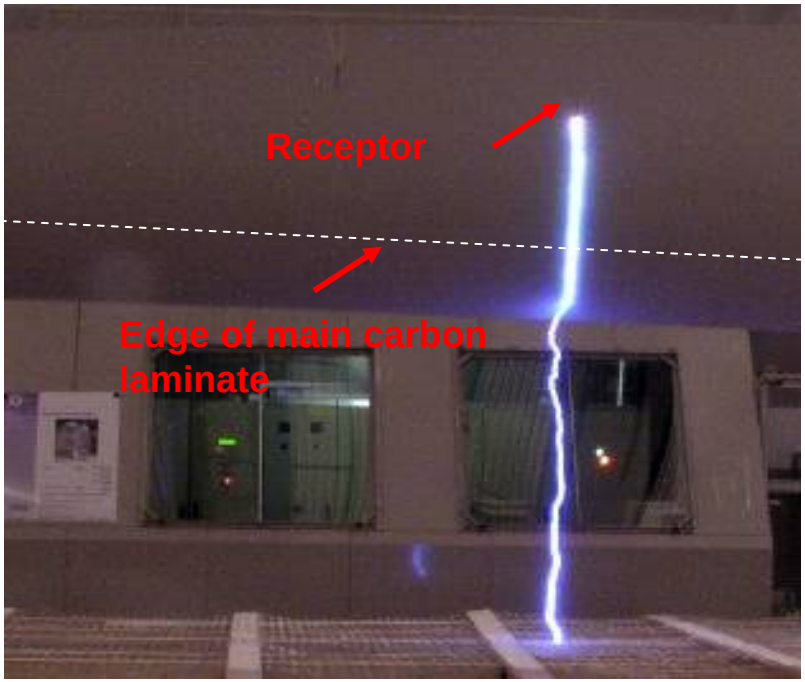
at 248 kA, 3.2MJ/ohm.

The LM DiverterStrip increases the ability to capture lightning strikes



No Diverters

Faulty strike to the edge of the carbon fibre laminate



LM DiverterStrip mounted

The DiverterStrip captures the lightning strike and leads the way to the receptor

Field experience also shows good results

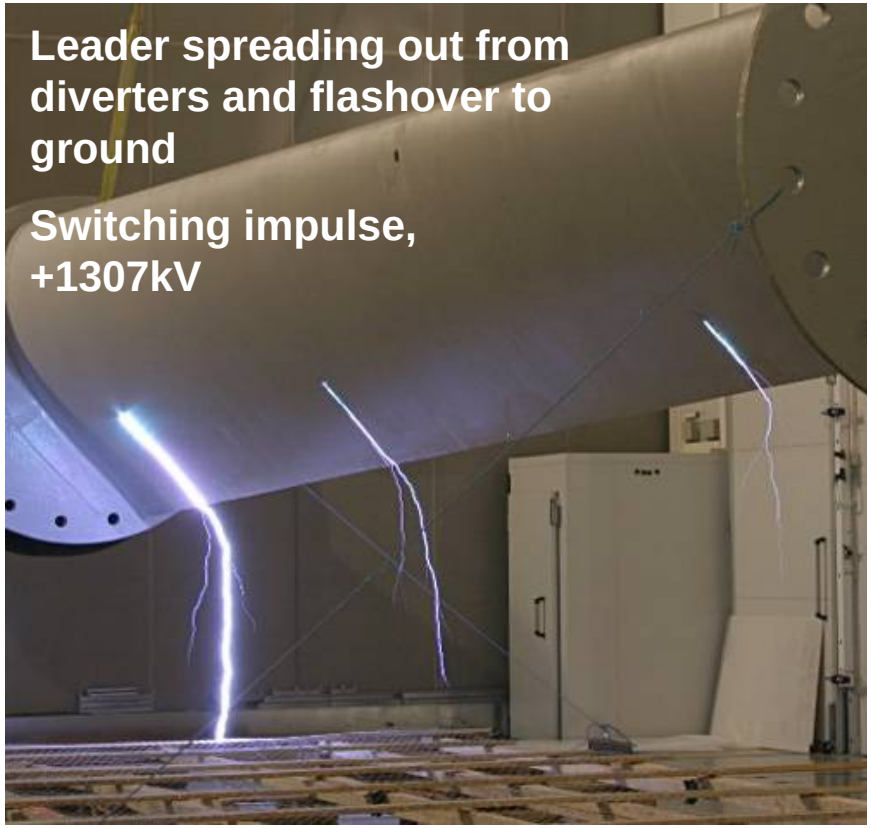
- The LM DiverterStrip is tested in the field on the LM 61.5 P in Brunsbüttel

- One year field experience shows good results, without any wear or damage to the DiverterStrips.

LM 61.5 P at Repower 5M in Brunsbüttel

Conclusion

- Lightning protection of carbon is a complex, but manageable challenge
- The semi-conductive carbon fibres impose higher risk of faulty strikes, internal flashovers
- Standard lightning protection system used for fibre glass blades does not provide sufficient lightning protection to carbon fibre blades
- The LM DiverterStrip increases the receptors' ability to capture the lightning strikes
- The lightning protection system has been tested according to IEC 61312-1 annex C level 1 and EUROCAE ED 105



Q&A

The presentation can be downloaded at www.lmglasfiber.com