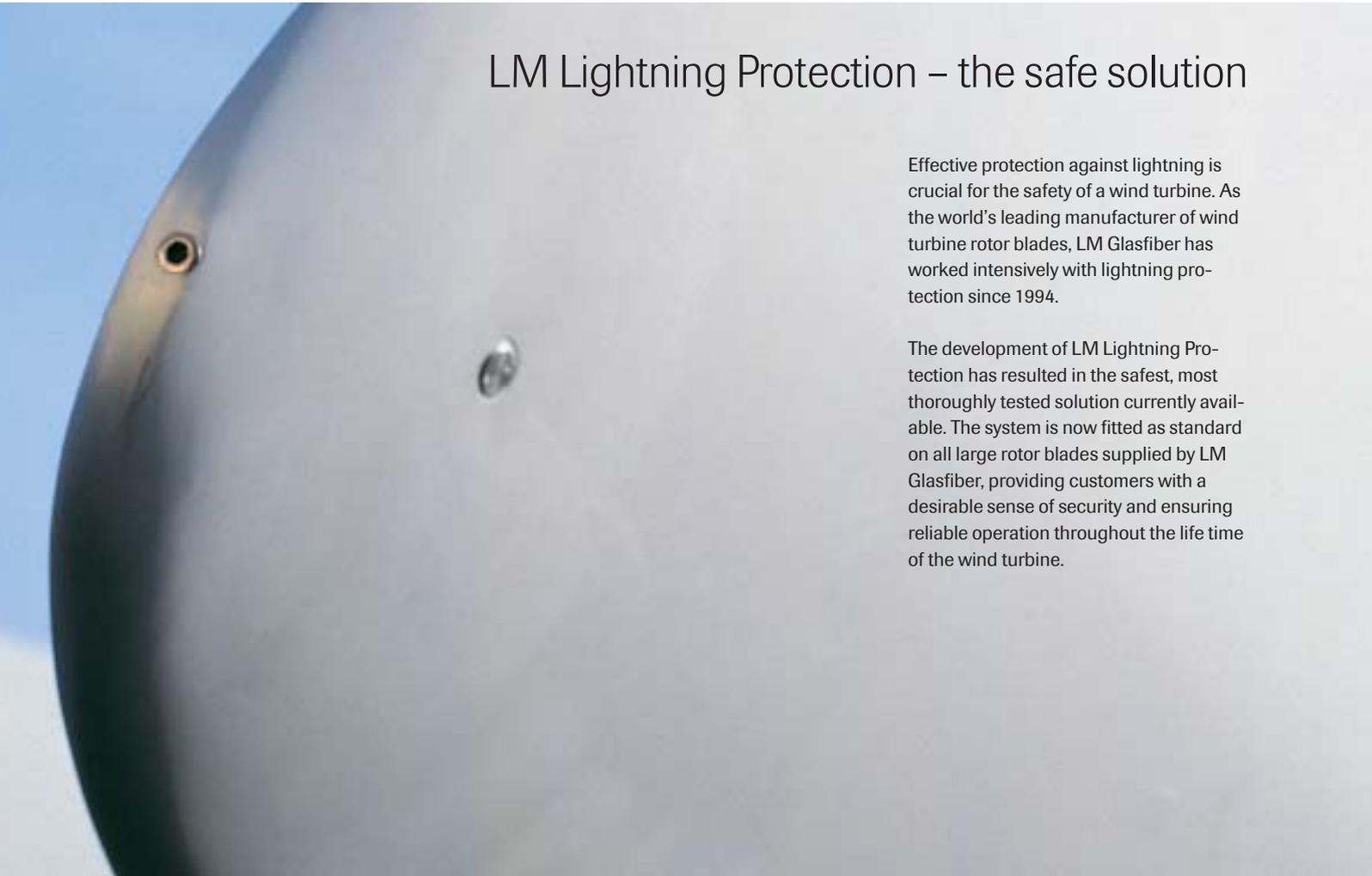


LM Lightning Protection

Taming the power of lightning



A close-up photograph of a white wind turbine rotor blade. The blade is curved and has a small, dark, circular component embedded in its surface, which is part of the lightning protection system. The background is a clear blue sky.

LM Lightning Protection – the safe solution

Effective protection against lightning is crucial for the safety of a wind turbine. As the world's leading manufacturer of wind turbine rotor blades, LM Glasfiber has worked intensively with lightning protection since 1994.

The development of LM Lightning Protection has resulted in the safest, most thoroughly tested solution currently available. The system is now fitted as standard on all large rotor blades supplied by LM Glasfiber, providing customers with a desirable sense of security and ensuring reliable operation throughout the life time of the wind turbine.

Taming the power of lightning

Lightning often strikes the highest point in a given area. This makes wind turbines a natural target, due to both their height and their elevated location. The blades are among the most expensive single components of a wind turbine, and a lightning stroke can have a highly destructive effect on an unprotected blade. LM Glasfiber has therefore devoted years of effort to dealing with the forces unleashed when lightning strikes.

Modern wind turbines continue to increase in size, with a corresponding increase in the risks of being struck by lightning. Wind turbines placed offshore are even more exposed to lightning strokes than their land-based counterparts.

The siting of offshore wind turbines makes it very difficult to undertake visual supervision of the blades, both because of general weather conditions and because the site is difficult to get to. Replacing components and carrying out any repairs made necessary by lightning strokes are much more costly than on land-based sites.

All of this presents a considerable challenge to lightning protection for the rotor blades – a challenge that LM Lightning Protection has tackled and beaten.

The nature of lightning

More than 2,000 thunderstorms are active throughout the world at any given moment, producing approximately 100 flashes of lightning per second.

The lightning bolts that stem from this differ considerably in nature. Their charge can be positive or negative and act in either direction – cloud to ground or ground to cloud strokes.

Most lightning creates one or more strokes of short duration. Multiple lightning strokes usually follow the same path. Strokes of long duration cause severe damage to the object on the receiving end. Lightning releases currents of up to 200,000 amps, and this amount of energy released

within an extremely short period of time results in the components of a wind turbine being exposed to powerful shocks.

The incidence and the types of lightning vary considerably from country to country and from one region to another. Both type and frequency also fluctuate on a seasonal basis. In some places, lightning strikes an average of once a year, while in others it is much more frequent. At the same time, the increasing use of wind power throughout the world means that lightning protection must prove its effectiveness in even the most demanding locations.



A lightning bolt can have a highly destructive effect on unprotected rotor blades. Protected blades, however, can often withstand being struck several times before it is necessary to replace the receptor.

The design of LM Lightning Protection is based on the fact that lightning usually strikes the blade at the tip.



An unprotected rotor blade is vulnerable

LM Glasfiber's extensive research has shown that lightning often strikes the outermost part of a wind turbine blade because this is the highest point. However, the longer the blade, the greater the risk of being struck by lightning along the blade surface.

An unprotected rotor blade is very vulnerable when struck by lightning. The stroke

creates an electric arc that extends from the point of contact via other conductive components down to the root flange, sometimes reaching temperatures of up to 30,000°C and causing an explosive expansion of the air contained within the blade.

The effects of this can include surface damage, pressure damage, delamination,

cracks in both the leading and trailing edges, and melting glue. Lightning strokes can also cause hidden damage that may lead to serious long-term problems, and significantly reduce the service life of the blade.

Documented protection against lightning damage

LM Lightning Protection is designed to effectively and safely intercept and transmit lightning to the wind turbine's lightning protection system.

Important milestones in the development of LM Lightning Protection include several years of intensive development, market feedback from a large installation and extensive full-scale testing in the most advanced high voltage laboratory currently available.

Results from tests using the very latest procedures available to the aviation industry document the effect of the LM Lightning Protection system.

The protection system complies fully with protection class 1, the highest standards of protection covered by the international CEI/IEC standards. This corresponds to 98% protection against all lightning strokes.

Great emphasis is placed on developing a simple, robust system with the same service life as the rest of the blade. LM Lightning Protection is therefore the best documented, most thoroughly tested and well-tried system currently available.

Relationship of lightning current parameters to protection levels

Selected lightning parameter		Protection level		
		1	2	3
Current peak value	I (kA)	200	150	100
Total charge	Q _{total} (C)	300	225	150
Specific energy	W/R (kJ/Ω)	10,000	5,600	2,500
Average steepness	kA/μs	200	150	100

Source: CEI/IEC 61024-1-1

LM Glasfiber Lightning Protection was developed and designed to conform with the international CEI/IEC protection level 1 standards.

Full-scale test of LM Lightning Protection

LM Glasfiber carries out extensive, full-scale laboratory testing to evaluate and document the LM Lightning Protection rating.

The testing method used was based on the very latest standardised test procedures for aeroplane components made of composite materials. These procedures were developed by the American and European aviation standardisation bodies, SAE and EUROCAE Aircraft Lightning Test Standard (Draft, 27 August 2002, revision A), respectively.



LM Lightning Protection – a thoroughly proven system

LM Lightning Protection is a carefully tested system that comprises two meticulously designed major components – the receptors on the surface of the blade and a conductive cable system leading down within the blade itself. When lightning strikes, the receptors intercept the lightning, and the cable system conducts the charge through the blade to the tower and then down to the earth.

Receptors are the points of conduction where the lightning actually strikes the blade.

These receptors are manufactured from a special alloy that has excellent conductive qualities and is resistant to intense heat. With repeated lightning strokes, the surface of the receptor will partly evaporate, but the alloy used here ensures that these receptors can withstand several strokes before they need to be replaced. Due to their simple construction, however, the lightning receptors are easy to replace if necessary. Compared with the materials

previously used, the new alloy significantly increases the service life of the receptors and decreases maintenance costs.

The lightning conduction system is the network of cables that conducts the lightning current from the receptors to the turbine's lightning protection system. After installing more than 45,000 lightning protection systems, LM Glasfiber has accumulated a wealth of experience about how to correctly conduct enormous quantities of electrical current without it short-circuiting to other conductive installations. It is equally important to ensure that the strong magnetic forces formed when the lightning current passes through the cable do not cause fittings to work loose or cause other damage to the blade and its equipment.

The way the system is built up ensures maximum protection against lightning damage. As much as 98% of all lightning strokes are intercepted and earthed without causing damage or interrupting oper-

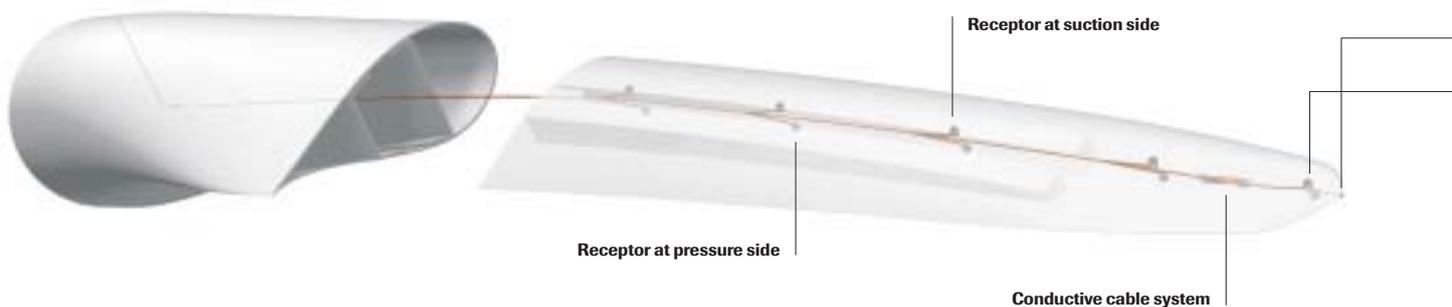
ations. This provides ideal operational protection throughout the designed life time of the turbine.

Improved protection for large blades with the LM MultiReceptor system

As turbine sizes have grown, the length of the blades has increased considerably. The ground-to-tip height of modern multi-MW turbines is thus greater, and this increases the likelihood of the blade surface being struck by lightning. Smaller blades are normally struck at the outermost part of the blade.

The LM Glasfiber MultiReceptor system was developed to eliminate this risk. The system consists of several receptors placed on both sides of the blade, 20 metres from the blade root towards the blade tip, as recommended by DEFU R25. Each receptor is capable of conducting the total energy generated by a lightning stroke to the main cable, on its own. Together, the MultiReceptors improve the lightning protection along the entire

The LM Glasfiber MultiReceptor system



length of the blade's surface, providing a safe and reliable solution for large wind turbines both onshore and offshore.

DrainReceptor – the safe combination

The LM Glasfiber DrainReceptor is a new kind of lightning receptor that combines the ability to intercept lightning strokes with a design that drains off condensation within the blade.

This is because condensation can form within the blades of a wind turbine, as the result of changes in the temperature of the surrounding air. It is essential that this condensation is drained off. Otherwise rotation of the blade will cause it to collect at the tip of the blade, which affects total performance. Blades that contain water also run the risk of overheating in the event of a lightning strike. This results in the formation of significant vapour pressure, which in extreme cases, can cause the blade to explode.

Previously, a drain hole was used to deal with this. However, close examination of data collected over several years reveals that there is a risk that lightning can strike the drain hole itself. By combining the lightning receptor with the drainage of condensation, this risk is eliminated.

Because it is placed right at the tip of the blade, the DrainReceptor also helps to protect the most exposed section of the blade. The DrainReceptor is constructed in such a way that it is easy to replace, if necessary.

The special DrainReceptor system was developed and patented by LM Glasfiber.

Valuable data – documented experience

LM Lightning Protection is based on carefully focused R&D efforts and on years of systematic work spent collating the results of extensive practical experience.

Rigorous laboratory simulations of extreme lightning conditions have been set up to ensure that both the system and the individual components are correctly designed and engineered.

LM Lightning Protection also includes a magnetic card that registers lightning strokes. This has provided us with a comprehensive, valuable body of data and experience, which documents that a considerable number of blades have been repeatedly struck by lightning without suffering damage.

This material forms part of a highly focused development effort. The goal is to develop and document the effectiveness of LM Lightning Protection still further – and to extend it for use with the very large rotor blades of the future.



Receptor

Due to its simple construction, the lightning receptor is easy to replace if necessary.



Drain receptor

The LM Glasfiber DrainReceptor combines the ability to intercept lightning strokes at the most exposed section of the blade with a design that drains off condensation within the blade.

Confidence and trouble-free operation

All wind turbines can be struck by lightning. For the wind turbine owners, it is crucial that such an event does not result in damage or in any interruption of normal operation.

All larger LM Glasfiber blades therefore feature LM Lightning Protection as standard equipment. The system is designed to capture and conduct even the most powerful bolts of lightning through the blade and down to the tower in a controlled manner. LM Lightning Protection is the most thoroughly tested lightning protection system currently available, with documented results. This provides you with security and the certainty of trouble-free operation.

As the world's leading manufacturer of wind turbine rotor blades, LM Glasfiber has always taken its responsibilities seriously. As progress is made in the general understanding of lightning, opportunities for providing even better protection against lightning strokes also become greater. LM Glasfiber thus maintains a constant R&D effort focused on this problem, in close collaboration with both customers and the world's leading experts in the field of lightning.

LM Lightning Protection enables wind turbines to utilise nature's energy – without nature's energy destroying them.

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