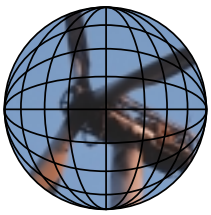

Fires are not a common occurrence for wind turbines – but when they do strike, they can be very costly. Prevention and protection are therefore essential, write **Nancy Smith** and **Eize de Vries**.

Wind and fire

Reducing the risk of fire damage in wind turbines

Incidences of wind turbines catching fire are, thankfully, rare, but when a fire does occur it almost always results in the total destruction of the turbine. Fire crews can do very little to tackle wind turbine blazes once they start – the sheer height of the turbines means that reaching them quickly is impossible, and fire engines cannot deliver sufficient water pressure to reach, let alone extinguish, a turbine blaze.

Once a wind turbine has burned down, it can lead to between nine and twelve months of down time, and therefore a considerable loss of income for a wind farm operator, according to insurers WindPro. (That said, the major manufacturers will frequently step in and replace the turbine as soon as possible – no company wants a burnt-out turbine 'on show'.) Figures suggest that fire damage accounts for between 9% (Umweltkontor) and 20% (WindPro) of the value of wind power insurance claims.

> Fire damage accounts for between 9% and 20% of wind power insurance claims

WHAT CAUSES WIND TURBINE FIRES?

Fires in wind turbines normally begin in one of two ways – a lightning strike or a technical fault. In both cases, the combination of either radiant heat or a spark with the transmission fluids or other lubricants is dangerous, and the plastics used in nacelle covers are highly flammable.

Lightning

Lightning does not necessarily lead to fire. Often, when a wind

Burn-out: turbine fires almost always result in total destruction
JAN OELKER

turbine is struck by lightning it can simply lead to repairable damage – typically a turbine blade will be smashed and need to be replaced. Yet if a lightning bolt sparks a fire, it becomes totally destructive.

Susceptibility to lightning damage is heavily dependent on a wind turbine's location – and its size. According to Birger Madsen of BTM Consult, continental Europe is susceptible to lightning strike – there is a relatively high frequency of lightning in the north of Germany and the Alps, while Denmark is rarely affected. Insurers WindPro say that lightning strike is significantly more common in the US than in Europe. Some Texan sites, according to Birger Madsen, have shown themselves to be particularly exposed to lightning. Parts of Japan have experienced severe lightning losses: a technical paper by Lightning Eliminators and Consultants (LEC), *A Study of Lightning Protection Requirements for Large Wind Turbine Systems*, also cites problems in one area of Japan during a particularly turbulent winter. The paper states: 'Data collected from one winter season in Japan alone reveals losses of horrifying proportions. In just one season, and just one area of Honshu, at least 55 machines had blades destroyed by lightning. The total estimates [that] one year loss for those machines exceeded $5.5 million, and the cost of prevention is approximately one half that value'.

As turbine size increases, so does vulnerability to lightning. Offshore wind farms also face a higher risk. Thus, lightning conduction becomes a more essential, and more standard, element of wind turbine blades. In particular, the growing trend towards use of (highly conductive) carbon fibre in the larger blades – as a way of adding maximum strength with minimal weight – increases vulnerability from lightning.

Madsen says that manufacturers will need to look at much more sophisticated lightning conduction measures as machines continue to grow. By way of example, Vestas has included a lightning protection system in its latest V90 model, which takes the carbon fibres' conductive properties into consideration. Such systems extend from the tips of the blades to the bottom of the tower, where an earthing system is installed.

Much more sophisticated lightning conduction measures will be needed as machines continue to grow and move offshore

However, some manufacturers are not making use of carbon in their large blades – as Eize de Vries writes in his article on page 52, a proposed redesign of the blades for the 5 MW Multibrid machine will leave out the carbon. And Enercon has avoided the use of carbon in the blades of its E-112 machine.

UK-based engineering specialist EA Technology is tackling the problem of lightning in a more preventative way with its Lightning Location System. The system predicts where lightning will strike up to two hours in advance, giving wind farm operators the option of shutting down turbines to avoid damage.

TURBINE DESIGN AND FLAMMABLE FLUIDS

About 85% of all turbines (reckoned on a megawatt-basis) sold worldwide in 2003 were conventional wind systems, with a drive train that typically comprises one or two main bearings, a main shaft, a gearbox, high-speed shaft, fail-safe brake, and generator. This type of system requires a large quantity of lubricant (oil). In these machines, the transformer is accommodated either in the nacelle or in the tower base.

The remaining, approximately 15%, share of the world market in 2003 was made up by turbines that use a direct-drive system. These contain a large ring generator, and do not need a gearbox. They therefore have no drive components that require a large amount of oil. On the other hand, the voluminous ring generators contain a significant quantity of (potentially) flammable resins.

In either case, any leakage of fluid can lead to problems.

According to EA's Benoit Dal Ferro, based on an average of 10 lightning strikes per year at a given location annual down time should be no more than four hours.

Technical faults and human error

The other main cause of fire is technical fault. Tracking the source of a fire, after the event, can take some time. Typically, as mentioned above, a fire that starts because of technical reasons will result from overheating, or sparking, in combination with flammable fluid or vapour.

Human error can also play a part. In the past, fires have been caused by loose or broken electrical connections, which can introduce sparks or heat. Nearby oil spills, grease, rubber cable linings, plastics covers and any other flammable materials can potentially be ignited.

Fires can also occur as a result of component failure. In 2003 the nacelle of the German 1.2 MW Vensys 62 prototype burned down, apparently due to a short circuit in a fail-safe battery pack of the pitch control system.

It can also happen that a bearing starts failing and runs dry. The resulting heat build-up in the component can finally – especially if combined with oil and or grease – lead to disastrous fires and consequent installation damage. Insufficient lubrication oil, failing cooling systems and other operational imperfections can also lead to problems which, under certain conditions, may lead to fire. Finally, a fail-safe brake running hot during a sustained brake action could be a potential cause of nacelle fire. Again, a combination of oil with grease spills increases the probability.

Turbine age

Another factor that affects susceptibility to fire is the age of the turbine. In the US, thousands of small wind turbines in the 80–150 kW range were installed in previous decades. At that time, it was very uncommon to fit lightning protection systems into the blades. As a result, lightning incidents resulting in a fire are more likely with these older turbines. Model and make are not thought to be particular factors, according to WindPro, though US wind veteran Paul Gipe has observed that old small-size Danish and German models are generally the most reliable,

and has recommended them as a 'best buy' in the second-hand market.

AVOIDING FIRE DAMAGE

Maintenance

Thorough and systematic service and maintenance is essential, and a thorough check of the entire installation is needed during each service and/or repair visit. It is important to make sure that cables are routed properly, avoiding situations in which a cable or a pipe can rub against rotating and/or vibrating components. (Damaged cable insulation can result in a short circuit.)

A broken or worn-through oil-circulation pipe can cause an oil leak, which can in turn lead to a machine component running dry and hot. If leaked oil comes into contact with either electrical contacts or hot machine surfaces, it can cause a fire. Broken or worn-through water circulation pipes can also result in overheating of components and lead indirectly to a fire. Frequent checks are therefore essential.

Condition monitoring

Condition monitoring systems – accessed remotely by PC – can greatly reduce the risk of component-induced damage. These systems typically monitor such things as oil and/or water temperature in critical components, (differences in) component vibration levels, and changes in acoustics levels, amongst other things.

Fire protection systems

There may also be a useful role for automatic fire extinguishers, functionally coupled to key system functions. Some turbine manufacturers are believed to be looking at incorporating these systems into their products, and the controlled environment within modern nacelles could now make this easier than it might have been in the past. Other patented systems, as used in different industries, are now offering themselves to the wind market.

One such product, which could be installed at any stage in the turbine's life, is from Firetrace. This product uses tubing that can be installed along any part of the internal workings of the wind turbine (for instance, parallel to the hydraulic lines) and delivers CO_2 or another fire-suppressant to extinguish a fire within seconds of its starting. This reduces damage to a minimum. The systems are designed to work automatically, without the need for manual activation and monitoring.

INSURANCE ISSUES

Insurance costs to the wind industry can be significant. In the case of a lightning strike to a large modern turbine, with blades measuring 30 metres or longer, the cost of replacing a single, damaged blade according to LEC can exceed $100,000. However, in the event of a fire, the insurance stakes can be higher. According to Fraser McLachlan of WindPro, insurers are often forced to pay the entire cost of replacing a turbine destroyed by fire. Even if the turbine is covered by a warranty

and an insurer or wind farm operator can prove a fire was caused by a fault, the warrantor is often only liable to pay for the cost of replacing the faulty part – which may cost just tens of Euros – and not the entire wind turbine, says McLachlan.

> A single, lightning-damaged blade can cost more than $100,000 to replace – and with fire, insurance stakes are far higher

So although fires are rare, once they happen, they inevitably lead to a hefty claim. WindPro figures show that fire accounts for 20% of their claims and leads to €4 million in pay-outs a year. According to insurers Umweltkontor, 9% of its claims costs are due to fire. Typically, an insurer will have to pay €1–1.2 million to replace a modern large turbine. That is why insurers are actively encouraging, and in some cases insisting, on risk-reduction methods being put in place, in order to reduce the threat of fire.

THE INDEPENDENT EXPERT

In some cases, insurers have insisted on regular inspections of wind turbines or even laid down guidelines for the replacement of parts. Risks of premature component failure caused by insufficient quality standards or poor quality of assembly can, say industry experts, be reduced significantly when a greater authority is given to the work and reports of quality inspectors. These independent experts, among others, carry out commissioning and end-of warranty inspections, and are usually in a good position to offer a balanced judgement on the condition of given turbines and specific turbine types and makes in general.

PREVENTION PAYS

Some insurers are asking customers to consider fire prevention as a way of reducing risk and premiums. Many insurers will offer discounts on premiums if fire-suppression systems were installed.

According to McLachlan, investment in a fire-suppression system could pay dividends in the medium term: 'They are not going to get the cost of the protection back in a year, but they will get it back over time. We expect clients to recoup the cost over a five- to seven-year period – probably closer to five years.' Considering that most wind turbines are expected to have a service life of up to 20 years, WindPro considers this to be a worthwhile investment.

It is attention to these main issues of fire and lightning protection and serviceability which will keep insurers happy, premiums down and fires at bay.

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