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"New Challenges for Wind Energy"

Construction works at Thornton Bank wind park, Belgium - 6 x Repower 5M units (© by Alpha-Ventus)

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Summary

The wind turbine industry has developed rapidly within the last 15 years and will continue to expand at an even faster rate in the next decade.

This paper deals with issues of the current situation such as the concern in respect of the potential of an increase in frequency and size of claims from physical damage and the ensuing business interruption due to the ongoing problem of serial defects of errors in design, poor quality components, insufficient internal controls and lack of good workmanship.

Therefore during the European Wind Energy Conference 2008 customers, financial partners and the insurance industry were demanding of manufacturers and suppliers to adopt general standards as applied by the car industry for improved quality, reliability and easier repair. This may take some time to become true.

Insurers should be aware of the current situation in this field of insurance and the need to acquire the engineering knowledge and underwriting and claims handling skills for handling this business profitably.

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New Challenges for Wind Energy

A) Ongoing Booming Demand

1. Environmental and Political Framework

1.1 Implications of the Kyoto Protocol for Wind Energy

The Kyoto Protocol was adopted in Kyoto, Japan in 1997 and came into force on February16th 2005. Its major feature is to set binding targets for 37 industrialized countries and the European community. The main target is the reduction of man made greenhouse gas (GHG) emissions by approximately five per cent from 1990 levels over the period from 2008-2012.

As a result of 150 years of industrial activity, developed countries carry the main responsibility for high GHG emission. Their burden has been enhanced through "common but differentiated responsibilities." Initially regional measures have to be taken and three market based options should be made available: emission trading (the carbon market), clean development mechanism and joint implementation. The international transaction log is located in Bonn, Germany and it is expected that the developed countries will initiate projects in less developed countries on the basis of a lower cost perspective.

The Kyoto Protocol contains no statement in respect of which technology should be installed to reduce the emission of GHG. Wind Energy as part of the so called renewable energies does not emit any GHG.

Even during their life time cycle modern Wind Turbine Generators produce between 60 to 80 times the energy consumed in their manufacturing process, which leads to a significant reduction of the emissions (source : www.Risoe.dk).
Therefore Wind Energy becomes a main topic all over the world to fulfil the targets of the Kyoto Protocol.

1.2 Expected Outcome of the Copenhagen UN Climate Change Conference in December 2009

The 2009 United Nations Climate Change Conference is scheduled to be held in Copenhagen in December 2009. It shall be the most important of the post-Kyoto Protocol negotiations on greenhouse gas emissions. Since February 2007, a series of international negotiations took place to develop the framework of a binding multilateral treaty that is intended to further reduce the man made impact on climate change beyond the 2012 targets. This treaty still is expected to be finalized in Copenhagen. Based on the 1990 level of emissions, it is expected to require a reduction of greenhouse gas by 2020 by a minimum of 30%. Some experts already believe this target to be insufficient to meet the defined overall target to stop global heating at not more than a 2°K change.

Among other topics, points of discussion will be
- new emissions targets,
- rural and transport electrification.

Plus the general topic of finance transfers for new technologies to those related most to wind energy.

Yvo de Boer, Executive Secretary of the United Nations Framework Convention on Climate Change calls as the essential questions of Copenhagen:

- How much are the industrialized nations willing to reduce their emissions of greenhouse gas?
- How much are the major developing countries such as China and India willing to limit the still rapid growth of their emissions?
- How to finance the engagement of developing countries in reducing their emissions?

Two major steps on the way to Copenhagen 2009 were not finished successfully. Even though announcements were made, the G- 20 summit did not agree on financial aid to poorer countries related to green energy. The Bonn Conference in April 2009 as a first preparatory talk for the coming Copenhagen treaty, ended in disagreement on most of the topics.

There are however two developments that give positive impetus to greenhouse gas reduction.
On the one hand the massive ongoing investment in the USA including added political pressure on the utilities. On the other hand the worldwide financial crisis has lead to a massive reduction in fuel consumption.

Three more preparatory talks will be held between now and December 2009.The main aspect will be the common effort to balance the process of reducing and replacing energy already initiated in some countries (i.e. the EU) versus those countries that are still in the need of general development. Those developing countries see the need to increase production and transportation based upon available fuels, even with a negative greenhouse gas impact.

2. Wind Power Market Overview

It should be noted that this report is based on statistics published in 2008, i.e. prior to the onset of the financial crisis in 2008. Therefore the report should be read with the caveat that the full effect of the global financial crisis is not yet known.

However, unlike the financial sector which has noticed the full effects of the general economic downturn, it seems as if the renewable energy sector is not affected to the same extent. The British Prime Minister Gordon Brown has stated to the EU that the financial crisis must not be an excuse for not investing in renewable energy and thus in CO_2-reducing measures - a statement which seems to have been well received in most countries around the world.

2.1 Status in 2008 and Forecast 2013

With roughly 28,000 MW of new installations in 2008, wind power grew by 30% in total installed capacity.

By the end of 2008, the world’s total installed capacity was estimated at 122,000 MW, with wind power being produced in approximately 34 countries.
By the end of 2013, the total installed capacity is estimated to be nearly 343,000 MW, increasing to 690,000 MW in 2017.

From 2009 to 2013, the average annual growth (CAGR) for wind power is expected to be 22.9%. In 2013, the total new installed capacity is expected to exceed 58,000

MW, which would be equal to the capacity of 58 nuclear blocks if wind speeds leading to full load operation were available at every time and wind turbine location.

2.2 Capacity Growth by Region 2009 – 2013

Growth is expected to be split as follows:

Europe	79,000 MW
Americas	65,000 MW
Asia	61,050 MW
Other	16,000 MW

2.3 Manufacturer Market Share - Top 10 Suppliers in 2008

Based upon best industry estimates, the 2008 estimated market shares of the leading manufacturers are:

Vestas (DK)	19.8 %
GE Wind (US)	18.6 %
Gamesa (ES)	12.0 %
Enercon (D)	10.0 %
Suzlon (IND)	9.0 %
Siemens (DK)	6.9 %
Sinovel (PRC)	5.0 %
Acciona (ES)	4.6 %
Goldwind (PRC)	4.0 %
Nordex (D)	3.8 %
Other	6.3 %

Of interest are the two Chinese (PRC) manufacturers who now rank amongst the leaders.

2.4 New Manufacturers

Due to the large demand for wind turbines, the price per MW of wind power has increased considerably, and several new manufacturers have entered the market. In China alone, there are currently more than 50 manufacturers, of which some will soon be interested in exporting their machines.

It is, however, a challenge to develop and manufacture a wind turbine which will successfully last its design lifetime of 20 years. Designing, producing and maintaining of such a reliable, high quality wind turbine is high-technology. Although it is possible to manufacture a low cost wind turbine, it is not to be assumed that the market will accept low cost and low quality wind turbines. This is proven by the fact that even large multinational groups face difficulties to establish themselves in the wind power market.

The major challenge for the next years is the development, design and manufacture of reliable offshore wind turbines. These can be considered a new, separate category. The extent and complexity of challenges that manufacturers are facing related to offshore construction and operation were unexpected for most.

B) Technological Development and Trends

1. New Technologies

1.1 Overview

New types and models of wind turbine are constantly under development.

Models are seen with several generators, others with new blade designs that optimise the output and improve efficiency by a few percent. One of the main obstacles in developing new and improved WTGs (Wind Turbine Generator) is the general life cycle demand and the lack of real life testing possibilities due to the size of the units and their load constraints.

In addition to larger and more efficient designs, there is an effort to improve reliability. Improved monitoring systems for conventional three bladed geared upwind turbines are now designed for early detection of problems, with further developments in respect of sensitivity. These monitoring systems notify the necessity of immediate service or the possibility of postponing the service to the next regular maintenance. Significant maintenance expense can be saved avoiding extra service calls, so manufacturers try to improve reliability and stability of operation.

1.2 Offshore

Currently the world's largest generators in serial production are 5 MW. Larger units are currently being tested

Offshore installation has also been a major factor in the cost of these wind farms, with offshore wind farms being approximately 200% more expensive than onshore wind farms. An estimated 10 % of the total project costs likely to be saved by utilising the new "PLACE AND PLUG TM" method suitable for 5-40 m´s water depth. Currently any standard installation vessel is in high demand and will spend 1 year for the erection of 100 offshore WTGs - a new Danish, patented, time reducing multipurpose installation vessel and method "PLACE AND PLUG TM" makes it possible to assemble and test the entire WTG including foundation in the harbour and install 200 offshore WTGs per year.

The fully assembled WTGs mounted on their gravity based foundations are floated onboard the vessel and placed on the seabed by letting water and ballast into the chamber. The vessel can load 3 assembled WTGs per shipment.

Obvious benefits are:

- A semi submersible multi purpose jack up vessel that can place monopiles as well as "PLACE AND PLUG TM"
- The just-in-time principle; a short financing period with only 14 days from factory to onshore installation; 12 hours installation time from arrival at offshore location
- Assembly is done onshore at low cost (1/10 of the cost incurred offshore); only one vessel has to access the installation site and the completed WTG is pre-tested onshore before shipment.

The installation vessel is self propelled and has a better ability to withstand waves (transport < 5 m wave height, installation is possible < 2 m wave height), which leads to less waiting periods for weather windows.

The "PLACE AND PLUG TM" also allows decommission and removing the WTGs after the operation (authorization) permit for re-establishment of the seabed. Limitations for the application of the “place and plug TM” are the necessary soft bottom conditions, and use only for small scale wind farms. The higher power output of offshore wind farms compared to onshore wind farms due to stronger and more consistent winds are expected to compensate for higher costs of installation and operation/maintenance.

Principle of PLACE AND PLUG TM

2. New Dimensions

2.1 Wind Turbines

Individual onshore wind turbines have gradually increased in size over the past 30 years from less than 1 MW to test units of 5 MW. In recent years, most wind parks have utilised wind turbine units of between 1.5 MW and 2.5 MW.

2.2 Wind Farms

The capacity of wind farms reflects local laws and geographic constraints. Spanish wind farms have traditionally been restricted to 50 MW, however it is common that multiple wind farms only use one larger utility transformer. In most European countries, wind farms are relatively small. North America and Australia are characterised by far larger installations with wind farm capacities of well over 100 MW. The increasing size of wind farms, and/or their shared utility distribution creates increasing concentrations of exposure for today‘s insurers.

2.3 Costs

From a relatively stable market in the early 2000s, wind energy became a very challenging market in the years immediately preceding the current economic crisis. Demand for equipment far exceeded the available manufacturing supply with the result of escalating costs of wind turbine units. Various reports indicated that year-over-year price increase in 2006 and 2007 was of 20% and more. A major challenge for insurers was to ensure that the values reported for insurance reflected this changed marketplace. Some insurers responded with endorsements limiting their liability if, at the time of loss, there were problems with the reported values.

2.4 Supply Chain Disruption

Of equal concern to insurers was the disruption in the supply chain created by the unprecedented demand. Most major wind turbine manufacturers had order books filled two or three years into the future. The manufacturers had their challenges as well as with the worldwide boom in resources creating an unprecedented demand for industrial and process equipment, leaving manufacturers struggling to obtain major components for their WTG units. New factories are being built; still there is an unavoidable delay in bringing this new capacity to the market.

The consequence for the insurance industry was an increase in frequency as in severity of damage. Components readily available in 2003, 2004 and 2005 became scarce thereafter. Delivery times stretched into months and the business interruption claims grew.

Only in recent months has a combination of new manufacturing capacity and the economic slowdown resulted in an easing of the supply chain pressures and the shortening of lead times.

2.5 Electrical Utility Exposures

It is inevitable that there will be a growing concentration of exposure as more wind farms are built. Availability of land and favourable winds will bring some geographic concentration. While many insurers focus on the reliability of the technology, two major exposures, closely related, are often underestimated.

The on-site transformer for the wind farm is the first critical item on which a failure leads to a 100% business interruption. For smaller wind farms the amount of the total BI loss may be less than the loss of a single wind turbine due to fire, but in some large scale wind farms, this on-site unit may have a capacity in excess of 100 MW and a replacement time in excess of one year.

The second aspect related to the point of exposure has emerged as the expansion of wind energy accelerated. In strongly developed wind farm areas, the feed-in point to the public grid of the local utility can be the highest exposure. In one situation a company had 19 wind farms delivering to the grid through a single substation. That company's exposure was large, yet it represents only one of the four companies using the same substation to feed-in energy. The aggregate power output was some 450 MW and the lead time for the transformer was well in excess of one year. The remoteness of many attractive sites for wind generation exacerbates this exposure. The grid connecting exposure can also be a concern in the USA, Spain and elsewhere as the power transmission networks are in need of major investments. It has been asserted that the average age of utility transformers in the USA already exceeds their Lifespan expectancy.

3. Repowering

Since the first major expansion of the wind industry in the 1980‘s, the development of wind turbine technology resulted in larger and more efficient turbines. Knowledge gained has improved massively the design and operation of both individual wind turbines and wind farms. The potential of applying this knowledge and technology to upgrade the original group of smaller, aging units to current standards is being researched in many countries. In some countries, studies indicated that up to 90% of targeted sites can be repowered.

3.1 Repowering Benefits

There are obvious benefits of repowering. Original wind farms consist generally of a large number of small turbines (less than 1 MW) spread over a large area. After repowering the energy output increased by 220% to as much as 430%. The basis for this dramatic growth in efficiency arises out of a few critical elements.

Today's turbines are larger and provide a better power curve. Taller towers often will bring the turbines 80 metres above ground instead of the 30 metres common in previous years. Higher hubs can take advantage of the more consistent winds at these altitudes. A German study proved an increase in full load hours of ranging from 13% up to 45%.

Repowering also results in fewer units. Repowered sites often consist of less than half of the number of former turbines, consuming significantly less space. In one of the first major US repowering actions the number of turbines was reduced from 179 to 38 by shrinking the space consumed from 2400 acres to 400 acres. Fewer units reduces maintenance costs and a less extensive supporting electrical distribution system,

In addition to efficiency and output gains, there are several environmental benefits of repowering. Newer units generally emit less noise and sometimes are of a more aesthetic design. As a significant environmental issue reported bird mortality is lower as the rotor of newer units is often above avian flight paths and turns slower. The modern tubular towers do not provide the ready nesting space of the old lattice towers.

Repowering enables increased power output without developing new sites. While some countries still have ample space for erection of new wind farms, in most European countries, lack of space is a serious concern.

3.2 Repowering Issues

Despite the advantages of repowering some obstacles also exist.

The major gains in efficiency result from the use of higher towers and modern design. In some countries, however, regulatory restrictions on height and space eliminate much of the potential efficiency gains. Power purchase agreements and tax benefits may not permit or support the repowering of the site.

Wind farm repowering is expensive. There are dismantling costs for the old turbines, towers and foundations, while the electrical networks and access roads must be replaced or upgraded.

One analysis concludes that a 250% increase in output is the threshold for economic viability. Even if a repowering opportunity meets all other criteria, in some countries there are still enough Greenfield sites available to make repowering a secondary area of interest.

Repowering of Wind Farms

C) Claims Issues

1. Serial Losses

Besides "normal" stand alone losses such as mechanical breakdown, serial losses are an ongoing severe problem for the wind industry. Practically all parts of a turbine have been affected by these events. To a lesser extent the problems have been caused during assembly and erection but mostly serial defects are matters of the pre-production sphere.

The common causes are often found to be defective material, defective workmanship or defective design. Problems can arise from either poor quality of material supplied, insufficient internal controls during the manufacturing process, the lack of good craftsmanship or (fatal) errors in design. Technically, it has been found that the responsible parties often lack awareness regarding the dynamic loads that the substantial components of a wind turbine experience.

The liability of the insurer for machinery breakdown claims arising out of defects depends upon the relevant terms and conditions as well as on the local national legal situations.

Defects are substantial faults in the components of the product caused before acceptance of the project. These defects are often hidden in the final work and eventually manifest themselves, causing damage to the installation years later. The most common symptom is abnormal wear and tear. Major known problems occurred both before and after 2004, affected foundations, gearboxes, generators and blades. From the German market, it has been reported that some 2200 turbines of the installed 21.000 turbines (end of 2008) suffer from defects in foundations, so some 10% of all foundations require rehabilitation. Add to these thousands of faulty blades, hundreds of faulty bearings and generators, it might be correct to think that 15 – 20% of all installed wind turbine units contain defects at the time of delivery.

Damage due to these defects in some cases is neither sudden nor unforeseen.

One of the most damaging defects at the moment to insurers' portfolio are problems with the foundations. Not all of those cases known today are related to a serial defect, but an impressive number of cracking structures is related to a very small number of models. Several experts have analysed the issue with agreement that the problems are related to dynamic loads. In some designs there was a misunderstanding of how these loads were conducted in reinforced concrete structures. The findings prove that the cracking starts on the underside of the foundation where it may stay unobserved for a long while. When the first cracks appear on the surface, these are often mistakenly held for 'normal' cracks from the shrinking process in the concrete. Worse, if the surface is covered by a fixed or glued coating, the true nature of these cracks remains invisible.

Since 2004, a number of different serial defects of foundations are known. Yet luckily, none of these caused casualties or collapse of the wind turbine installation.

There was a public demand in a discussion platform during the European wind energy conference (EWEC) 2008 from customers and financial partners that the manufacturers and suppliers should dedicate themselves to the general standards of the car industry. There was a general commitment of representatives of the industry that is not to be expected to keep these limits of quality control and product tracking for the next years. Since then it might be visible that manufacturers try to regain the confidence of clients and banks. Investments in research and development facilities in the last two years have increased considerably, but it is most probable that it will take years until these efforts will show appreciable results.

Observation of significant numbers of claims on identical parts and models is a must. Information gained from our market may give a greater understanding of potential problems. Once a serial defect is suspected, the manufacturer or supplier should as a rapid response minimise the extent of loss.

To get information about upcoming problems to the clients might be a chance to prevent excessive claims in future, but always remains last resort.

Despite all the efforts to improve quality control, we still expect serial losses in the future.

Serial defects in foundations

2. Fire Losses

Fire damage is often very extensive and results in a total loss of the WTG. In most cases, there is no automatic fire extinguishing equipment in wind turbines. In the Risk Consideration Section E of this paper the approach to minimising the risk of fire will be discussed.

D) Onshore vs. Offshore farms - Specific Risks

1. Type of Damage

Damage to offshore wind turbine projects occurs most commonly from:

a. Cable laying between the wind turbines.
Usually, the cables are damaged by the contractors as a consequence of negligence or lack of skill. Installation of sea cable requires trained staff with experience and knowledge in this difficult environment, together with the right equipment.
Without the right people and good equipment, things very often will go wrong.

b. Damaged export cables.
Export cables are often very expensive, as in most instances, the damaged piece of cable will have to be replaced rather than just spliced. Export cables are stronger and much more expensive than the cables between the wind turbines. These cables require large, specialised vessels, increasing the likely cost of repair still further.

c. Handling of wind turbines.
During erection, damage from collision or total losses to blades and nacelles can also occur.

2. Additional and Different Costs

Offshore wind farms have some elements of cost that are not found in their onshore counterparts:

a. Costs which may occur in connection with the hiring of contractor vessels and equipment for the repair of damage.
Costs for the hiring of vessels can easily amount to EUR 100,000 per day. This daily rate will include standby charges payable as a result of poor weather conditions. Weather conditions in the North Sea from October to April may make it impossible to carry out repair work for several weeks due to rough sea and strong winds.

b. The actual offshore repair works are also more costly and sophisticated than onshore repairs. Everything is more difficult in handling, and mistakes are difficult to correct. Planning needs to be very detailed, and it is important that all staff, equipment and tools are in place. Everything must be on time on site - sounds simple, but can be rather difficult to coordinate.

c. Wind turbines should not stand idle for several months due to the risk of standstill marks on bearings. In order to avoid damages, a diesel powered generator must rotate the turbine. The costs of this diesel generator may easily amount to EUR 100,000 for a four months delay.

d. It is a prudent for the client and the contractor of the construction to agree in the contract on a charter price for repair works, even if the costs may be covered by insurance.

e. A detailed contingency plan is necessary when working with complex tasks such as the erection of an offshore wind farm.

3. Aspects regarding Delay in Start Up or Business Interruption

a. Poor weather conditions can delay the repair work considerably and the amount payable for business interruption could be extremely high in connection with, for example, damage to a 200 MW wind farm.

b. The export transformer is a bottleneck. Even in case of slight damage to the export transformer or its cable, the wind farm could stand idle for several months. Four month delays have been experienced in some claims. If repair works are more difficult, the idle period could easily extend to 12 months or more. It is very important that a schedule is prepared in advance for such idle periods due to the necessity of rotating the turbines to avoid standstill marks on the bearings.

c. The new very large 5 MW wind turbines are often technically complicated and their size makes them difficult to handle. It may take 10 days just to prepare dismantling of a large wind turbine and another 4 days should be added to this for the actual dismantling. As a result, a waiting period of 14 days does not provide much protection for the insurance companies.

E) Risk Considerations

1. Certification

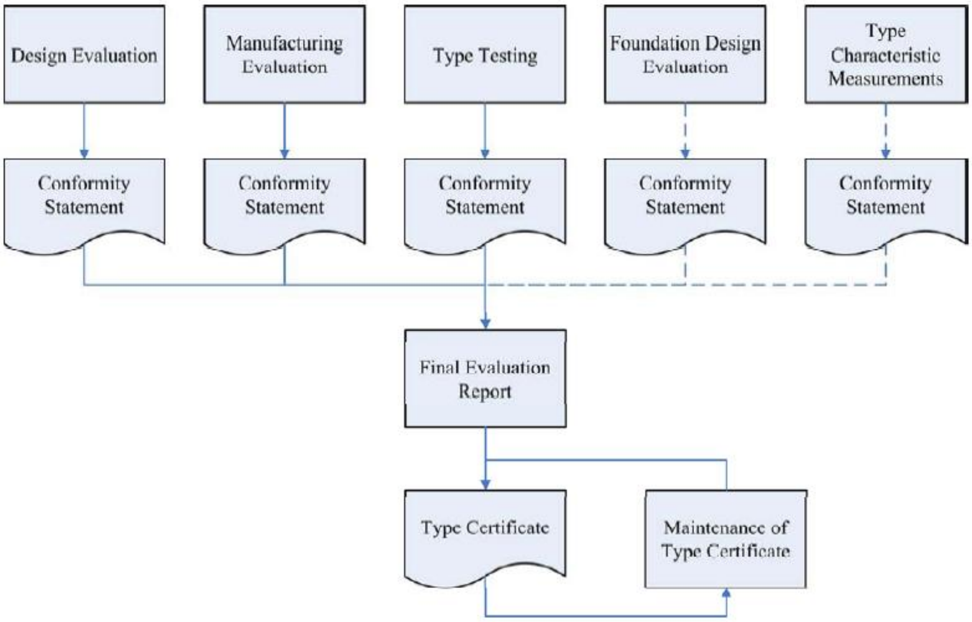
Certification is a very important tool in improving and ensuring the quality of the overall wind turbine fleet. Historically, each country has handled the certification issue individually. During the late 1980s, Denmark developed a formal wind turbine type certification. Separately, Holland, Germany and USA developed a type certification. For all jurisdictions, the goal was to achieve a consistent and reliable wind turbine.

There is now a worldwide certification based upon the IEC standard WT-01 Type Certification system which itself is based upon the IEC standard IEC 61400-1 (Design Requirement), 61400-2 (Design Requirement for small turbines) and 61400-3 (Offshore).

The WT-01 certification covers

- Type certification (divided in WTG and small WTG)
- Prototype certification
- Project certification (divided in Land-based and Offshore)
- Component certification

The content of the IEC 61400 certification can be found in detail in Appendix 1.



2. Fire Protection

As discussed earlier, fire remains a serious hazard for WTGs and as most operational covers for WTGs are all risk covers, the “property perils” are included. The market increase in WTG asset values, in conjunction with increasingly difficult WTG operating conditions in offshore applications, demands the development of reliable fire protection systems.

The need arises especially with a view to damage containment in the event of a fire. Fires experienced to date in "onshore" WTG installations have led to high claims to insurers, not least due to an absence of fire detection and automatic protection

systems. The local fire-fighting services, in the vast majority of cases, will at best be able to ensure a controlled burn-down of the WTG without undue risk to people and surrounding property.
The risk of a total loss of the WTG must be rated as very high for the relevant insurer if no effective fire detection and protection system is in place.

Moreover, today's long procurement lead times for replacement equipment will usually imply long business interruption periods in the event of a total WTG loss. To the insurer these may translate into a clearly increased likelihood to provide indemnification to the full limit of the contractually stipulated liability term. If the agreed indemnity period is not sufficient for this event, the excess loss will be borne by the wind farm operator.

The following key risk features give rise to an increased exposure in the event of a fire in a WTG:

- high value concentration in the nacelle;
- concentration of potential ignition sources in the nacelle, plus increased risk of a lightning strike;
- unmanned operation;
- impossibility of fire-fighting interventions due to great equipment height;
- remote and at times hard-to-reach WTG sites, especially in the case of offshore equipment.

Despite the high values and known risks automatic fire protection is rare in WTGs. Due to the exceptionally high exposures in offshore facilities, there is an emerging trend to provide automatic fire protection systems in the newer developments.

2.1 Causes of Fire

The causes of fire in onshore and offshore installations are, in principle, alike and therefore comparable. The probability of technical defects - and hence, the magnitude of the fire risk – must be viewed as higher in offshore equipment due to the difficult marine environment. This means an increased exposure of offshore WTG in addition to the fact that our experience with offshore applications is still limited at present. (note – we say there is an increasing trend in the previous paragraph)

2.1.1 Lightning

The claims experience recorded to date has shown that lightning strike is among the most frequent causes of fire damage in WTGs, given the equipment's exposed location and elevated hub heights. The fire risk will be even higher when a lightning protection system is absent, poorly designed/executed or has not been given adequate maintenance:

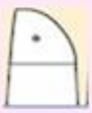
The philosophy for lightning protection was changed several years ago. Instead of isolating the installation from the ground, today, the lightning current is led through the entire construction in a controlled manner. This has been quite successful as the cost of claims caused by lightning damage is estimated to have been reduced by 50%.

Today minimum requirements for an effective lightning protection system include the following:

- systems protecting the rotor blades;
- defined lightning conduits for conveying away the lightning current ;
- overvoltage protection of electrical equipment.

Lightning Protection System

Apart from the tower, the nacelle and the wind measuring system, the rotor blades are potential lightning strike targets. For an effective protection of the blades from the effects of a lightning strike, various technical solutions exist. These are summarized below, along with their respective advantages and drawbacks.

	Advantage	Disadvantage
Copper mesh around the entire blade tip 	▪ Easy to laminate into blade surface. ▪ No discharge into interior of blade through the blade structure ▪ Protection of the entire blade	▪ Susceptibility to destruction of the mesh structure at strike point ▪ Difficult to repair and replace
Replaceable metal tip or cap 	▪ Fairly low melt-out damage at strike point ▪ Replacement is possible	▪ Complex/costly design and attachment to glass fibre structure ▪ Conductive connection for discharge must be provided
Replaceable metal receptors 	▪ Fairly low melt-out damage at strike point	▪ Small arrester area, no protection of edges at blade tip ▪ Complex/costly design ▪ Conductive connection for discharge must be provided
Metal sections (in blade edges) 	▪ Fairly low melt-out damage at strike point ▪ No discharge into interior of blade through the blade structure ▪ Additional protection from lateral lightning strike	▪ Complex/costly design and attachment to glass fibre structure ▪ Not easily replaceable ▪ Need to be designed for the requisite fatigue strength under variable stress

Advantages and drawbacks of various rotor blade protection systems

Lightning current discharge path

Lightning hitting the metal receptor is discharged to the ground via a steel rope passed through the interior of the rotor blade and connecting the receptor to the steel structure (blade flange – nacelle – tower).

A basic prerequisite for all lighting protection systems is adequate grounding, i.e., a low-impedance discharge path guiding the lightning current from the equipment to the ground.

2.1.2 Electrical Equipment

Apart from lightning, defects in electrical WTG equipment – e.g., the power converter, transformer or control electronics – are among the most frequent causes of fire. These may have their origins in a failure of the WTG control unit, a circuit breaker defect, inadequate electrical protection, or diverse other factors.
Additional potential causes of a fire include the following:

- Hot surfaces (mechanical break, overheated bearings, etc.);
- Execution of hot work within the WTG.

2.2 Fire Protection Measures

In order to minimize the fire risk associated with WTG operation, potential fire and explosion hazards must be identified by the manufacturers before the planning phase and taken into account in the design of the equipment. This will include the step of providing the WTGs with a lightning and overvoltage arrester system adapted to the equipment. The lightning and overvoltage arrester system must specifically cover the rotor blades, the nacelle and the tower, apart from integrating all other operationally vital and safety-relevant WTG components.

Moreover, the following must be observed in the planning and WTGs operating phase:

2.2.1 Reduction of Combustible Materials

In designing a WTG system, the use of combustible materials such as PU or PS plastics, which are very often employed for lining the nacelle housing, should be eliminated altogether. Where the use of non-combustible materials is not feasible, flame retardant types should be selected. In addition, the materials employed should have a washable surface so that any accumulation of foreign matter (e.g., oil) will be effectively controlled.

Where equipment components contain combustible fluids which may leak or spill out during repair or maintenance work, it must be ensured that these can be safely collected and disposed of. It should also be noted that no combustible material must ever be stored within the WTG.

Cables and wiring should be designed to exhibit the following properties in the event of a fire:

- minimum release of toxic or corrosive decomposition products
- low emission of smoke and contaminants
- no facilitation of fire propagation

2.2.2 Avoidance of Potential Ignition Sources

All WTG components representing a potential ignition source should be designed such that no fire will be caused by them, regardless of the equipment's operating condition. A strict compliance with earthing rules and regulations is necessary.

The mechanical brake of the WTG system should be equipped with a brake disc cover fitted in such a manner that the release of sparks during braking cannot ignite any combustible materials.
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Other potential ignition sources include the following:

- lightning current;
- short circuits and arc-over in electrical equipment;
- hot surfaces (e.g., bearings, brake discs);
- self-ignition due to contaminated cleaning rags (e.g., oils, solvent).

2.2.3 Maintenance of the WTG

Technical defects of mechanical and electrical equipment components are among the most frequent causes of fire. In order to minimize these causes, maintenance of the WTG per manufacturer's specifications and timely repairs are imperative. In addition, technical equipment and monitoring systems must be inspected at regular intervals by experts on site, in line with accepted rules of technical practice.

2.3 Fire Detection and Fire Fighting

Fire damage in a WTG should be contained by a local fire detection system which detects any incipient fire. This is because no other early detection means exists, given the unmanned operation of wind power stations. The automatic fire detection capability must be designed to signal to the control system and to trigger the installed fire extinguishing system automatically. In addition, the WTG must be automatically shut down.

Among fire detection systems, a basic distinction is made between space monitoring and equipment monitoring types

2.3.1 Space Monitoring

Interior (e.g., nacelle, tower) and exterior (transformer, substation) areas containing WTG components must be monitored by the fire detection system. The fire alarm sensors employed have to be designed for the specific ambient conditions (temperature, air humidity, etc.). For monitoring within the WTG, alarm sensors should preferably operate on the smoke detection principle. Since operating conditions will vary, e.g., as a function of the mounting location within the WTG, the suitability of the fire alarm sensors employed should, as a matter of principle, be examined together with the system vendor for each specific application. The same applies to the equipment monitoring solution described below.

2.3.2 Equipment Monitoring

Technical components which are

- encapsulated;
- ventilated or cooled by a forced air stream;
- operated in rooms with high air change rates;

should be monitored by means of an equipment monitoring system, over and beyond the space monitoring functionality. As with space monitoring, smoke should be the fire detection criterion and the suitability of the fire alarm sensors should be examined on an application-specific basis in coordination with the system supplier.

Depending on the type of space or equipment monitored, fire alarm sensors may be of the following types:

- smoke detectors;
- heat sensors;
- flame detectors;
- multi-sensor smoke detectors.

An automatic early fire detection capability will only be helpful if the alarm messages emitted will actually give rise to an initiation of appropriate further steps. These will include the rapid communication of alarms to the relevant fire-fighting services, the shutdown of the WTG, and an all-pole disconnection of the WTG from mains. In addition, the (space and equipment) fire extinguishing systems must be automatically activated.

2.3.3 Fire Fighting

In the event of fire, the extinguishing media used in a WTG must be residue-free, non-corrosive and non-electrically conducting, if at all possible. Moreover, they must be suitable for the existing fire loads and application conditions.

Depending on the application, the following fire extinguishing media may be selected:
- CO_2 fire extinguishing systems;
- inert gas fire-extinguishing systems;
- water mist fire-extinguishing systems;
- water spray fire-extinguishing systems (for transformer stations and substations).

Powder and aerosol-type fire extinguishing systems are not recommended for use within WTGs because of the consequential damage they may potentially cause.

Given the multitude of parameters and boundary conditions to be met, the suitability of the fire-extinguishing system to be installed must be examined for each individual application. In particular, it will be necessary to select the fire extinguishing medium in accordance with the existing fire load and within the properties of the equipment component to be protected.

3. Condition Monitoring

The aim of condition-based maintenance, which has proven its merit in all areas of power generating technology for decades, is to maximize component utilization by extending the equipment’s service life. WTGs should be no exception to the rule that continuous status supervision with the support of online conditioning monitoring systems (CMS) ought to be a tool employed in any comprehensive maintenance scheme. This is a prerequisite for trouble-free equipment operability and, at the same time, high availability rates. The main task of a CMS is to detect deviations from normal operating level on the basis of structure-borne noise produced by the monitored components.

By detecting when a monitored component exceeds pre-defined limit values, the operator and technical operations manager of a wind farm will be able to implement a timely, effective and cost-efficient response, in co-operation with the insurer. This will minimize the necessary repair times and costs while avoiding prolonged shutdowns and the associated consequential costs, e.g., due to the lack of spare parts.

An efficient monitoring of WTGs poses special demands on the condition monitoring systems used. In order to demonstrate that a CMS will meet real-life operating requirements while ensuring a high information quality of the measurements obtained, only certified systems are to be employed.

3.1 Structure and Function of a CMS

The operation of a condition monitoring system is based on the measurement and analysis of vibrations emitted by the monitored WTG components. Depending on their geometry, mounting location and rotational speeds (r.p.m.), typical kinematic frequencies can be attributed to each individual component of a WTG power train (antifriction bearings, gear wheels, shafts). These measurement signals are reproducibly detected by the installed sensors and then analysed by means of software. Significant changes in measured vibrations form the basis for diagnosis and the generation of alarm messages. In evaluating the vibration analysis, variables characterizing the equipment's operating status (e.g., wind direction, wind velocity, etc.) are likewise taken into account so that condition-related vibration changes can be distinguished from operationally induced ones.

The backbone of each CMS is the multiple signal transducers fitted on the monitored WTG components and the associated software which, among other things, executes the measuring functions and signal processing. Suitable signal transducers may include the following:

- structure-born noise sensors (detecting sound waves and flexural vibrations in solid bodies), e.g., acceleration sensors sensitive to acceleration of the measuring point on the component surface that arises as a result of structure-born noise waves and bending of the component;
- rotational speed (r.p.m.) sensors.

Arrangement of an r.p.m. sensor in a WTG

An acceleration sensor is usually made of piezoelectric material. Due to their operating principle, structure-born noise sensors exhibit a very poor sensitivity at low frequencies (e.g., slowly rotating shafts) due to the very small vibration displacement or vibration velocities (and hence, fairly low acceleration levels) involved. For monitoring such components, it will be found more useful to use sensors capable of detecting frequencies below 1 Hz.

Through the use of additional sensors, e.g.

- displacement transducers
- vibration velocity sensors
- temperature sensors.

Further measurement variables can be incorporated into the diagnosis.

The following WTG components should be subject to continuous monitoring by a CMS:

- rotor shaft, main bearings
- gear transmission
- generator
- nacelle and tower

Schematic views of a WTG power train with online CMS and structural-noise sensors

3.2 Limit Value Monitoring

Limit value monitoring is key to any automatic detection of status (= condition) changes. As a general rule, suitable limit values must be set for any analytical method employed. These need to be defined in at least two stages, i.e., including a preliminary and main alarm. In order to minimize the number of potential false alarms, a decision on measures to be implemented should be preceded by a review of the alarm messages by the responsible diagnostic staff member. It must also be ensured that the equipment operator is informed of this development in a timely manner so that he will be able to initiate the necessary steps, taking into account applicable recommendations for action. The latter may range from recommending a future repair to initiating the emergency shutdown of the WTG.

When a limit value is reached, the following information should be communicated to the operator:

- information about the wind park concerned, WTG No. and sensor/parameter
- date on which the limit was exceeded
- priority level
- recommendation for action (observe trend, schedule a repair, etc.)

To permit a subsequent analysis and allocation of potential defects, any retroactive modification or deletion of such data must be excluded.

3.3 Trend Analysis

The representation of trends over time represents an important evaluation instrument when limits are exceeded since it facilitates an understanding of the historical evolution of vibration characteristics. This makes it possible to provide necessary and suitable recommendations for action to the equipment operator. Moreover, trends in vibration behaviour can be detected at an early point before predefined limit values are exceeded.

The available data base should span the entire monitoring period. A reduced data base will compromise the information quality and may give rise to inaccurate diagnoses.

4. Oil Analysis

4.1 Online Particle Counts

Online particle counts on gearbox oil constitute another element of condition-based WTG maintenance. The aim of this technique is to quantify the particle abrasion on antifriction bearings and gear teeth. The normal wear process taking place during operation of the gearbox involves an abrasion of metal particles, especially as damage to antifriction bearings and gear teeth progresses. The number of such particles is assumed to correlate with the degree of such damage. According to what we know today, approx. 60-200 particles will be detected per month on an intact gear unit of a Megawatt-class wind power plant. With a severely damaged antifriction bearing, the number of metal particles detected has been known to reach up to 1,500 per day. To obtain reliable information on the mechanical wear status of the gear unit, trend monitoring is indispensable. For an early detection of an imminent failure it is not the absolute particle count that matters but the increase in the number of particles over a defined period of time.

The functional principle is described below for an online particle count. Those systems have been repeatedly employed in wind power generating plants.

The sensor is fitted in the oil recirculation circuit of the gearbox – more specifically, in the return line upstream of the filter. This configuration ensures that each particle will be counted only once before being removed by filtration.

Thanks to the inductive measuring method the system is capable of detecting both ferrous and nonferrous particles. To this end, two coils create a magnetic field within the sensor. The metal particles passing the sensor with the oil flow will produce a change in this neutral field. This change is detected by a third coil. The resulting signals reflect the number of metal particles which have passed through the sensor

Sensor operating schematic

4.2 Purity Analysis

According to the certification guidelines established by Germanic Lloyd (GL) for wind power plants, the gearbox manufacturer must provide a written manual documenting the relevant gearbox maintenance and monitoring instructions which need to be observed for the gear unit to reach its rated service life. This document must include binding information on the requisite periodicity of oil (including oil purity) analyses, as well as oil change intervals.

A comprehensive analysis of WTGs transmission oil provides information on the condition of all oil-wetted gearbox components. Oil analyses must be regularly carried out and compared; they form the basis for obtaining reliable information on

- wear and tear
- the presence of impurities such as dust, water, etc.;
- the condition of additives;
- oil ageing.

A basic prerequisite for obtaining high-quality analytical results is a representative oil sample taken during operation of the WTG or soon after its shutdown. For trend analyses, the sample must always be taken at the same point of the gearbox.
The parameters listed below by way of example must be documented in any laboratory analysis of transmission oil samples:

4.3 Viscosity (mm²/s)

Viscosity is the most important physical characteristic of oil. It is responsible for the oil's ability to protect surfaces from wear by building up a hydrodynamic lubricant film. An increase or drop in viscosity may be attributable to diverse factors, e.g.

- oil oxidation due to temperature or time in service;
- intermixing with other oil types.

Viscosity Index

The viscosity index is determined by measuring the dynamic viscosity at 40°C and 100°C. It is a characteristic variable which permits an easy comparison of the behaviour of different oils. The higher an oil's viscosity index (VI), the less its viscosity will change at different temperatures. The viscosity index is calculated in accordance with DIN ISO 2909.

4.4 Neutralization Number

Base oils are mixed with additives to improve their anti-friction and anti-corrosion properties. These additives are formulated around slightly acidic compounds. The surfaces of gearbox parts are protected through the formation of easily removable metal salts on them. The quality of an oil deteriorates when its acid content increases, promoting the corrosion of iron. To neutralize these acids, important additives are consumed and will therefore not remain available in sufficient quantity for anti-friction (wear protection) purposes.

The neutralization number indicates the amount of potassium hydroxide (mg KOH/g of oil) needed to neutralize the acid in the lubricant.

4.5 Water Content (ppm)

Water in the transmission oil may substantially reduce the service life of lubricated parts by facilitating corrosion. In addition to corrosion, increased metal fatigue may occur on component surfaces when the lubricant film is interrupted by water droplets.

4.6 PQ Index (mg/kg)

The PQ index is a characteristic variable indicating the total amount of ferrous particles in the oil, regardless of particle size.

This information enables the equipment operator to adapt oil change intervals to the relevant operating conditions. Oil is a raw material which should be used in a more sustainable manner; to this end, oil changes should be carried out as a function of the oil's condition. At the very least, however, an oil change becomes inevitable when the oil can no longer fulfil its functions due to contamination, ageing of additives, mixing with other oil types, or significant changes in viscosity.

A combination of the methods of

- online CMS;
- online particle counting;
- oil analysis;

will clearly enhance the effectiveness of any condition-based maintenance effort.

5. End of Warranty Surveys

In every project the goal for all parties involved must be to avoid claims as a claim normally both costs money and delays the project. Risk management is therefore a skill of high importance in the insurance business. Formally or informally every risk which can happen during a construction period is evaluated by a consideration of the cost and the frequency of the risk.

The effort and money used for this evaluation will depend on the consequence of damage. And as the expenses of all work done offshore are approximately ten times that of the similar work done onshore- The efforts put in order to avoid claims are substantial. One of the important actions to avoid claims offshore is the use of warranty surveys done by a warranty surveyor.

The warranty surveyor can be nominated either by the insured or by the insurance company. In both cases it must be agreed and he must be chosen from a named panel with proven skills. As an example he could be chosen from:

- London Offshore Consultants
- Global Maritime
- Noble Denton Associates
- London Salvage Association
- Det Norske Veritas (DNV)
- Germanischer Lloyd
- Survey Association Ltd. A/S

Beside technical skills he must show documentation on good physical health.
In general the scope of work is to follow the project from the early stage to the takeover.

According to the MR Special Offshore Wind Farms Insurance Cover (CP insurance endorsement - 1215) which is the common used wording the warranty surveyor shall:

- be involved from early stages of the project
- review and approve procedures and their execution and issues certificates on the project (as applicable)
- review and assess the suitability of vessels and tools engaged for the project
- attend and verify critical paths of the project
- specify recommendations to be met (where necessary) in order to comply with the terms of the warranty
- issue a report which documents his work, findings and recommendations

All of these bullet points are specified in a specific scope of work which divides the work into action points which require either an approval or a certification by the warranty surveyor.
It should be mentioned that a project can involve more than one warranty surveyor each with separate skills, e.g. in respect to foundations, vessels or cables.

F) Guarantee- Service and Maintenance

1. Guarantee Period

Normally, a manufacturer’s warranty period lasts for two years, but most manufacturers offer warranty extensions.

2. Willingness to meet/service Guarantee

The manufacturer’s willingness/ability to meet his warranty obligations is very difficult for a buyer to assess, unless experience in the market has been gained from any previous experience with the specific WTG manufacturer. There are instances where a manufacturer has not met, or only reluctantly met his warranty obligations, and where damage, which should be covered by a warranty, is claimed from the insurer of the operational cover. The manufacturer's willingness or the lack of it, to meet his warranty obligations is an issue that attracts much attention from both the insurance industry and the client.

3. Compliance with Service Period
Normally, it is a condition of cover that the wind turbine is serviced in accordance with the manufacturer's directions and within the service deadlines specified by the manufacturer. Damages due to the fact that the wind turbine has not been serviced within the specified time period can lead to a denial of claim.

G) Requirements on Persons working with Wind Turbines

1. Qualification
A modern WTG actually is a power plant, and must be treated as carefully as such. Only qualified persons are allowed to work with wind turbines, as untrained persons may cause severe damage to themselves or to the wind turbine. Unfortunately, there were cases where unqualified persons have lost their lives due to their lack of knowledge/experience.

2. Knowledge and Experience (Hardware/Software)
Carrying out service and repair work requires training and knowledge, and preferably experience, in relation to both hardware and software. The updated version of software and service manuals must be available as well as access to spare parts. Intervention in the control system of a wind turbine requires knowledge, and unqualified persons must not be entrusted with such a task. Even qualified persons have caused total damage to wind turbines as they did not have sufficient experience with control systems. This applies to service companies as well as to the employees of manufacturers.

3. Training
As mentioned above, it is essential that everybody involved in the erection, servicing, repair and maintenance of wind turbines has the necessary training. When considering the large number of new wind turbines entering the market, it may be difficult to ensure that the wind turbine industry has a sufficient number of trained staff. It is therefore desirable that wind turbine manufacturers as well as service companies are able to provide documentation showing that their employees have the necessary experience. In respect of service companies, it is necessary to establish certification schemes similar to those awarded to manufacturers, e.g. ISO 9001 and others.

H) Conclusions

The Kyoto Protocol has set binding targets for 37 industrialized countries and the European community for reducing man-made greenhouse gas emissions (GHG). The expected outcome of the United Nations Climate Change Conference in Copenhagen in December 2009, the most important post-Kyoto-Protocol, is to define a further target – the reduction of GHG by a minimum of 30% in 2020.
Though the Kyoto Protocol contains no statement in respect of which technology should be installed to reduce the emission of GHG. Wind Energy as part of the so called renewable energies does not emit any GHG.

Even during their life time cycle modern Wind Turbine Generators produce between 60 to 80 times the energy consumed in their manufacturing process, which leads to a significant reduction of the emissions (source : www.Risoe.dk) Therefore Wind Energy becomes a core strategy throughout the world to meet the targets of the Kyoto Protocol.

The wind turbine industry has developed rapidly within the last 15 years and will continue to expand at an even faster rate in the next decade.
Market figures for the industrialized and the developing countries demonstrate this growth. Even in the current financial crisis it seems as if the renewable energy sector is not affected to the same extent as other industrial sectors.

It is important to note that the technological development may have reached a stage that could compromise the designed lifetime of at least 20 years for a WTG. Of equal concern is also a disruption in the supply chain created by a booming demand - leading to an increase of frequency and size of claims from physical damage and the ensuing business interruption.

For many manufacturers it may well become an issue critical to their survival if the quality of design, manufacturing and maintenance of their equipment is not satisfactory to their customers.

A major challenge for the insurance industry is the ongoing problem of serial defects due to errors in design, poor quality components, insufficient internal controls and lack of good workmanship. Major components affected by serial losses include foundations, gearboxes, generators, bearings and rotor blades. It is reported that in the German market over 10% of the installed WTGs may suffer from undiscovered serial loss defects to foundations alone!

Therefore a demand from customers, financial partners and the insurance industry during the European Wind Energy Conference 2008 was the dedication of manufacturers and suppliers to the general standards of the car industry. Since these standards are not likely to be fulfilled within the next years, serial losses will still occur. However, by employing the improved monitoring systems, those defects can be discovered as early as possible. This may lead as a result to defects being less frequent and costly as they have been in the past.

All these different aspects of the wind energy industry show to insurers, who wish to specialise and profit in this field, that they should be willing to invest heavily in engineering knowledge, underwriting risk management and claims handling.

Addendum 1

IEC 61400

To give an impression of the content of the standard IEC 61400 please find a list of documents which are included:
61400-1: Safety Requirements (Large Turbines)
61400-2: Safety Requirements (Small Turbines)
61400-3: Safety Requirements (Offshore Turbines)
61400-4: Gearbox Design Requirements
61400-11: Acoustic Noise Measurement Techniques
61400-121: Power Performance Measurement Techniques
61400-122: Verification of Power Performance of Individual WTs
61400-123: Power Performance of Wind farms
61400-13: Measurement of Mechanical Loads, Tech Specification
61400-21: Measurement of Power Quality
61400-23: Full Scale Blade Testing
61400-24: Lightning Protection
61400-25: Communications for Monitoring & Control
Accredited Certification Bodies.

Addendum 2

Interesting Internet Information

www.alpha-ventus.de
www.bmt.org
www.btm.dk
www.erneuerbare-energien.de
www.fino-offshore.com (Webcom to view Alpha Ventus)
www.ewea.org
www.gwec.net (GWEC Global Wind Report 2008)
www.irena.org (in the course of foundation)
www.offshore-stiftung.de
www.vds.de (Wind turbines Fire protection guidelines VDS 3523 2008-07)
www.wind-energie.de