IMIA - WGP5(99)E

IMIA

Insurance of Wind Turbines

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July, 1999.

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Examples of interesting Internet information:

www.ewea.org
(The European Wind Energy Association)

www.wind-energie.dk
(The German Wind Energy Association)

www.ens.dk
(The Danish Environmental and Energy Ministery)

www.windpower.dk
(The Danish Windturbine Manufactures Association)

www.risoe.dk/amv/
(The Danish Risoe National Laboratory)

www.danmarks-vindmoelleforening.dk
(The Danish Wind Turbine Owners Association)

1. Introduction

Purpose of the report

The purpose of the present report is quite simple: to summarise and pass on the most important experience from the insurance of wind turbines.

What is far less simple, however, is the subject-matter insured – the Wind Turbine. The number of technological, historical, political, financial and environmental (why, even emotional) aspects relating to the subject of Wind Turbines is such that anyone discussing it must necessarily submit to the art of moderation.

Readers must therefore bear with the authors of this report for not providing an exhaustive, global picture of developments in, and the deployment of, wind turbines, and the advantages and disadvantages in terms of insurance related thereto.

Moreover, as the utilisation of wind energy for power production is widely different from one country to the next, the aggregate volume of experience described in this report will naturally relate to countries in which the use of wind power is widespread. Thus, the report's conclusions and recommendations should come as no surprise to insurers operating in these markets, and so the report is intended primarily for insurers operating in markets which have not yet had an opportunity to familiarise themselves with the joys and sorrows of wind turbine insurance. Anyone wishing to know more about, for instance, the technological development of wind turbines, the financial and/or (environment) policy-related aspects, etc., should know that the volume of information on wind turbines is huge and even easily accessible via the Internet. A list of the best and most informative websites on the subject can be found on the lindex page.

The history of wind energy

Man has extracted energy from the wind for centuries. First (and foremost) for marine propulsion and in the form of windmills which, by grinding corn and pumping water, provided a supplement to the muscular power of men and beasts.

In the wake of the development of the practical possibilities of producing and using electricity in the 1800s came, of course, the discovery that wind could be used for power production, and around 1890 the very first actual wind turbines for power production were installed by persistent pioneers. Installations were few and sporadic, and not until during and after World War I do we see a more systematic development and deployment of wind turbines in some countries.

The manufacturing, installation, running and maintenance of wind turbines soon proved to be so cost-consuming that, in terms of finance, power produced by wind energy failed to hold its own in the competition with coal-fired power plants and the expansion of nationwide power grids. Thus, until the worldwide increases in oil prices caused by the oil crises in the early 1970s, practically the only surviving wind turbines were those sited in remote locations, typically on large farms, far away from the power plant grids.

Such individual-use wind turbines are of course still found in countries such as Australia where, for reasons of distance, the possibilities of establishing nationwide grids are limited.

The price increases of oil in the early 1970s (and the rub-off effect they had on coal prices) opened up for the development of power-producing wind turbines, although the earliest of these efforts were founded on idealistic/ ideological grass-root movements' wishes to produce non-polluting, alternative energy from renewable sources. Some countries which lacked other renewable energy sources required for power production (e.g. hydropower) incorporated the utilisation of wind energy in their national energy policies in the early 1980s, and with the introduction of various subsidy schemes, tax advantages, etc., this resulted in a systematisation of the technological development leading to the mass production of a large number of wind turbines with a rated output of up to 50 kWh.

In the course of the 1990s the size of the individual wind turbine has grown considerably, and power production by wind turbines is no longer the exclusive area of the original, idealistic grassroots but is now in the hands of professional production companies. In some countries a major proportion of power is now produced by wind turbines (up to as much as 10% of the total power production), and there are examples of wind turbine manufacturing having grown into a large-scale industry with a sizeable turnover and considerable employment opportunities.

2. Electricity production

Wind energy production
As mentioned above, the extent of power production by wind turbines varies greatly from one country to the next and depends upon a number of factors the most important of which are, of course, the geographical, topographical, and geological conditions. Also, wind energy still cannot compete with those forms of production which are based on the traditional sources of energy (coal, oil, gas and nuclear power), at least not if measured on general market economy terms. Consequently, the development of wind turbine energy depends strongly on the individual government's environment and energy policy (no public subsidies = no wind power).

The table below shows the top ten of wind power capacity installed at year-end 1998.

Country	Wind energy year-end 1998 (MW)	Capacity installed per capita (W/p.c.)	Growth rate 1997-1998 (%)
1. Germany	2,875	35.1	38.2%
2. USA	1,820	6.8	8.8%
3. Denmark	1,448	275.3	26.1%
4. India	968	1.0	3.0%
5. Spain	707	18.0	38.1%
6. The Netherlands	361	23.3	13.2%
7. UK	333	5.7	4.4%
8. China	214	0.2	28.9%
9. Sweden	165	18.7	35.3%
10. Italy	154	2.7	49.5%
11. Others	517		
Total	**9,563**		**24.3%**

Source: The German Wind Energy Association

Future developments

It would seem that, within the field of wind turbines, even the most optimistic forecasts of future developments are constantly challenged by actual developments. As far as the technical aspects are concerned, only a few years ago the most competent technical experts said that it would not be possible to produce wind turbines with outputs above 250 kW. Today, wind turbines of 1.65 MW are mass produced. As far as energy output is concerned, the European Wind Energy Association predicted in the early 1990s that in the year 2000 the total European wind turbine capacity would be 4,000 MW. With an annual growth rate of some 40% this level was reached already in1997, when Europe's total capacity installed came to 4,500 MW. This led to a review of the original target for 2000, which has now been doubled to 8,000 MW. An updated target for 2010 is 40,000 MW of wind energy in Europe.

It is not for this report to decide whether these target are realistic. However, in our capacity of insurers we must necessarily take a stand on, and prepare ourselves for, possible future challenges, and it seems likely that the rate of developments and growth within the entire field of wind turbines, which has hitherto been very fast, will continue in the years to come.

This assumption is underlined by the presence of strong political forces (in Europe at least) which are working in favour of a continued and fast expansion of power production based on renewable energy sources. In one of its white papers, the EU Commission has stated its strategic target as being a doubling of the proportion of power production in the EU accounted for by renewable energy sources, from the present level of about 6% to 12% in 2010.

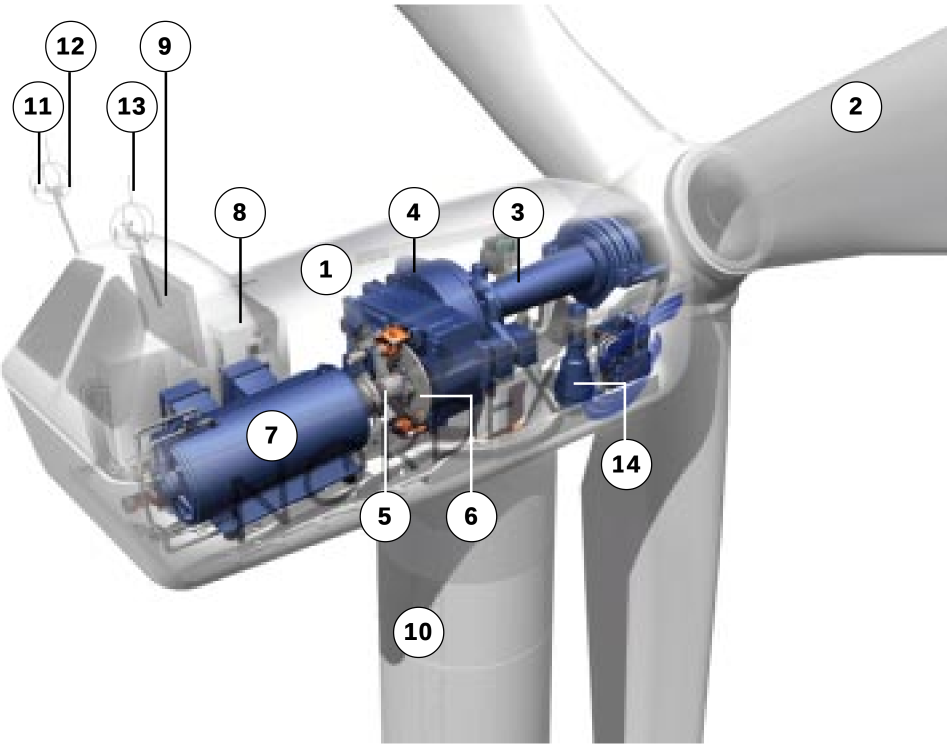
At the global level, the industrialised countries have committed themselves to reducing the total emissions of CO2 by 775 million tonnes by the year 2010, corresponding to an overall reduction of CO2 emissions of 30%; a commitment they made at the conferences on climatic change arranged by the UN in Buenos Aires and Kyoto. There is no doubt that an expansion of global wind energy capacity as one of the renewable energy sources will play a very important role in the fulfilment of this target. Today about 0.1% of the global power demand is met by wind power, and with the agreements on renewable energy sources made at national and international level it is expected that some 10% of the world's power supply will be covered by wind power around the year 2017. This means that insurers need to prepare themselves for strong growth in the demand for wind turbine insurance in the years ahead.

The targets set by politicians for an expansion of wind energy capacity can be met by means of different types of regulation. Among the options mentioned by the EU Commission are the setting of minimum prices for production based on renewable energy sources, binding minimum quotas for the purchasing of energy generated from renewable resources by established power companies, and national development plans for suitable wind turbine sites. Another option is already used in Denmark and involves imposing a duty upon electricity grid companies to provide grid connection points to all publicly planned wind turbine sites of a certain capacity, and ordering power companies to install their own wind turbine facilities of a certain capacity both on shore and offshore.

3. Wind turbine technology

Wind turbine basics

The basic construction of a wind turbine builds upon a relatively simple principle.



1. **The nacelle** contains the key components of the wind turbine and is accessed from the tower (10).
2. **The rotor blades**, each of which is some 20m long on a 600 kW turbine.
3. **The low-speed shaft,** which rotates relatively slowly, from about 19 to 30 revolutions per minute.
4. **The two speed gearbox,** which makes
5. **the high-speed shaft** rotate approx. 50 times faster than the low-speed shaft.
6. **The disc brake,** which is used in case of failures in the aerodynamic brake and when the turbine is being serviced.
7. **The electric generator** – either a so-called induction generator or an asynchronous generator with a typical maximum output of 600 kW.
8. **The electronic controller** for the monitoring of operations, the initiation of emergency stop, e.g. in case of overheating, and remote monitoring and reports to the operator.
9. **The cooling unit** for cooling of the generator and cooling of oil in the gearbox.
10. **The tower,** which is usually some 60m tall.
11. **The yaw mechanism,** which holds the mill up against the wind by means of electric engines (14).
12. **The anemometer and wind fane** which measure wind speed and direction for use in the automatic starting, stopping and turning of the turbine.
13. **Lightning conductor**
14. **The electric jaw engine**

Technological developments

Although a closer look at technological developments could be interesting from a technical (insurer's) point of view, only little space will be devoted to the process linking the very first 'modern' power-producing wind turbines of the 1970s to present-day (and future) turbines

It goes without saying that, over the years, experience and product development have caused improvements to be made to all parts of the wind turbine, but basically the past 10 to 15 years have brought no fundamental changes to the central wind turbine principles. The most visible change is, of course, the growth in the rated output of mass-produced wind turbines, whose generators were rated between 25 and 50 kW in the 1980s, but which now have a typical rating of 600 kW and produce between 1 and 2 million kWh a year, corresponding to the annual power consumption of about 300 European households. In terms of size the latest generation of mass-produced wind turbines has grown to twice its former size and has generators rated between 1.0 and 1.65 MW.

Product development and research, particularly within aerodynamics, have also resulted in a 5% annual increase in the energy yield per square metre of wind turbine rotor area over the past 15 years, and in a 50% reduction of weight and noise levels over the past 5, respectively 3, years.

Specifically with regard to operating safety and limitation of damage, mass-produced wind turbines have been improved over the past 10 to 15 years in the following respects in particular:

- The so-called open generators are no longer used, and this has reduced the occurrence of corrosion damage caused by humidity.
- The gearboxes have been developed in relation to their ability to resist impact caused by changing speeds.
- The gear wheels in the gearboxes now have inclined toothing to increase power transmission and reduce noise.
- The gears now have oil coolers to extend the intervals between oil changes and increase the useful lives of the gears.
- The noise insulation in the nacelle was previously inflammable but has now been replaced by flame-retardant materials.
- The disc brakes have been shielded so as to avoid a scattering of sparks in the nacelle.
- The brake strategy has been changed so that the generator is disconnected from the grid as late as possible in order to use the energy of the generator to slow down.
- The rotor blades now have lightning conductors as the risk of lightning cannot be minimised merely by insulation. By means of the so-called receptor method the electric charge from the lightning is captured by a receptor built into the tip of the blade, diverted from the vital parts of the turbine and taken through the tower construction to the ground.
- And lastly, modern wind turbines allow the remote monitoring of production data for ongoing control of the vital components.

The above overwiev is a general trend. Of course the insurer must carefully observe if the improvements are being implemented in the turbines to be insured.

4. Insurance of wind turbines

Development of the products

In the 1980s, when the installation of wind turbines in the countryside became more systematic, it was believed that fire and storm insurance was sufficient cover for a wind turbine, and insurance would typically be transacted by insurers' property units.

However, as the number of wind turbines grew and the individual turbine got bigger and represented a higher financial value the demand for a more specialized cover increased, and it became increasingly clear that insurance of wind turbines belonged under the heading of engineering insurance. As a result, specialised insurance is now available which recognises the wind turbine for what it really is, i.e. a power plant. This type of insurance is adjusted on an ongoing basis and in step with developments in claims experience and technological developments.

As a general rule, insurance cover of a wind turbine is arranged by its owner. However, certain markets have seen both owners and producers demanding insurance cover as part of the overall package when buying/selling a wind turbine. Consequently, in some places it is not unusual for a wind turbine manufacturer to arrange and pay up front for a five-year non-terminable wind turbine insurance as part of the fulfilment of an order for new wind turbines.

A comparative study

It will have appeared from previous sections that the extent to which wind turbines are systematically used for power production is widely different from one country to the next. This means that there are equally wide differences in the extent to which insurers in the individual countries have been able to gain experience from the insurance of wind turbines. Furthermore, wind turbines are still a relatively new subject-matter within insurance, and even one which is undergoing constant and very rapid technological development. This means that even insurers in countries with many wind turbines often have only a very modest basis of experience, and it also means that recent experience needs to be reviewed on an ongoing basis in step with technological developments.

To get an overview of all insurance experience gleaned at the global level, the authors of the present report sent a questionnaire to all IMIA countries. Regrettably, only about half of the countries replied, and of these several had even been unable to reply to all the questions. It is therefore impossible to give an exhaustive, overall IMIA overview of the insurance situation and experience.

However, it is possible on the basis of the questionnaires returned (for which we thank the contributors) to draw the following main conclusions, in particular in relation to the insurance products in those countries in which wind turbines are used to a certain extent:

As stated above, it is standard procedure to arrange insurance of wind turbines by means of specialised products which consider a wind turbine to be a power plant. In most countries All Risk insurance provides cover of Machinery Breakdown, Short Circuit, Storm and Fire. Similarly, in most countries (but not all) the insurance may also cover Loss of Profit and Liability. However, there are considerable differences as to whether cover is provided for Loss of Profit as a consequence of damage to the distribution grid without damage to the turbine. The period of cover for Loss of Profit differs from 3 months to 12 months.

In most countries, the insurance typically covers costs of crane assistance in case of damage, however with wide differences from one country to the next with regard to whether the insurance covers costs of road improvement in connection with the making good of damage.

In addition to the more standardised types of cover some countries also offer special cover, such as e.g. earthquake, legal advice, occasional performance and low performance (as a consequence of faulty wind calculations by manufacturer).

It proved impossible to obtain information on premiums and claims. Nor was it possible to deduce anything from the questionnaires returned on the subject of sum insured, deductible, and the like.

However, it could be established that the premium level for All Risk / Machinery Breakdown is usually calculated at between 5 and 8 per mille of current value.

With regard to main risks in connection with insurance of wind turbines, most insurers consider Machinery Breakdown and Lightning to be the largest risks, with Short Circuit and Fire having a somewhat lower priority. The calculated risk of Storm varies (for good reasons) from one country to the next, depending on local conditions.

Experience and results so far

As mentioned above, it proved impossible to obtain any specific information on insurers' experience from insurance of wind turbines in relation to e.g. finance. However, in the section below on insurance claims there is an overview of the experience gained from claims made in a market in which wind turbines have conquered a relatively prominent place in the production of energy.

Based on those very markets in which wind turbine insurance is now quite common, it is possible to sum up the general experience with regard to this type of insurance as follows:

- Insurance cover of modern wind turbines should not be arranged by means of a standard (property) fire and storm insurance policy.
- A wind turbine is a power plant and should be treated as such for insurance purposes.
- Technologically speaking, wind turbines are an extremely rapidly growing research object, and the insurer cannot rely on arranging insurance of present-day turbines on the same terms as applied to insurance of yesterday's wind turbines.
- Only insurers willing to, and capable of, allocating resources on an ongoing basis which enable them to keep abreast of the technological developments with regard to wind turbines can expect to gain positive experience.
- As is the case for other machines/turbines, the calculation of premiums and the determination of conditions must consider factors such as maker's guarantee, inspection and maintenance, faulty design, use of new or low-cost materials, upgrading of performance, fire safety, and the like.

- Wind turbines differ from other machines/turbines in particular in being sited in remote areas (both on shore and offshore) and by being located well above the surface (of the ground or the sea), a fact which determines both the contents of the insurance conditions, the calculation of the premium, and precautionary measures.
- It applies to wind turbines in particular that there are several excellent international and national type approval schemes (see below). As a result, insurers can (and should) take into account an array of technical factors and potential problems by arranging insurance only for those wind turbines that are approved under such schemes.

5. Insurance claims/damage

More than 10 per cent of power production in Denmark is contributed by wind turbines, and the wind energy capacity installed per capita in Denmark is many times higher than in any other country. Consequently, insurers operating in the Danish insurance market have been able to accumulate relevant risk data on wind turbines for a number of years already.

The table below, which does not necessarily reflect the risk situation in other countries, is based on 15 years of experience in Denmark. The figures come from wind turbine claims for which repair work began within 24 hours of damage having been discovered, and for which access roads were already available.

Type of Claim/Damage	% of Number of Claims	% of Cost of Claims
Mechanical	40%	40%
Lightning	20%	25%
Fire	7%	9%
Storm	4%	2%
Liability	0.5%	0.2%
Others (LOP, short circuit, etc.)	28.5%	23.8%

The following sections are devoted to a (very brief) survey of the experience gained from the typical types of damage.

Mechanical damage includes both damage to the actual machinery and other types of damage suddenly occurring to the wind turbine, e.g. mechanical damage to the rotor blades other than damage caused by lightning or storm.

The most frequently occurring type of mechanical damage is damage to gears. Damage may happen to bearings due to breakdown or wear (pitting), backlash and tooth breakage. These types of damage usually occur due to defects in material, fatigue, the use of wrong oil or wrong oil temperature, vibrations and overloading. Damage caused exclusively by wear (pitting) will usually not be covered by the insurance.

Minor types of gear damage can often be repaired on the spot, whereas more serious types of damage, which involve the lifting of major spare parts up to the nacelle, often find a more worthwhile solution in a replacement of the gear, as this will reduce the interruption time and requires only one call for a crane. Moreover, it will often be possible to sell the damaged gear to the manufacturer. The repair time at the gear manufacturing plant and the time of delivery of spare parts will usually determine the choice of repair method.

Mechanical damage may also happen to the rotor blades. So-called edgewise vibrations which arise in case of an (unfortunate) combination of a specific temperature and a certain wind speed may cause the rotor blades, and even the whole wind turbine, to start shaking to the point where, in the worst case, the result is a total loss. These edgewise vibrations have proven to cause problems especially in relation to 19.1m rotor blades which are usually found on 600 kW wind turbines.

However, actual loss which is covered by the insurance and which is caused by edgewise vibrations can be avoided if the safety system of the turbine has a feature enabling it to stop the turbine automatically if it registers too large vibrations. This may of course involve an operating loss for the owner which will not, however, be covered by the insurance as no damage is done to the wind turbine. Moreover, although they may not necessarily cause any damage or interruption of operations, these vibrations may reduce the useful life of the rotor blades considerably.

The problem of vibrations should have been solved for wind turbines produced in recent years through improvements to the construction of the rotor blades.

Damage by lightning is the second most frequently occurring type of damage. However, the extent of damage differs widely from one case to the next. Damage by lightning can be anything from a case of minor damage to the electric control panels to a case of total damage to rotor blades, gearbox, generator, and control system. Damage by lightning may be followed by consequential damage to machine parts and generator due to, among other things, ‘wounds’ caused by the electric charge of the lightning.

Failure to install protection against lightning will cause the electric charge to travel through rotor blades, gearbox, generator and to the control panel where it may cause considerable damage.

Damage by fire in wind turbines is usually caused by overheated bearings, a strike of lightning or sparks thrown out when the turbine is slowing down. The possibilities of fighting a fire in a wind turbine are often severely hampered due to the height of the tower, inadequate or non-existing access roads, or sitings in the countryside (or offshore) far away from the nearest fire-fighting service. Consequently, even the smallest spark can easily develop into a large fire before discovery is made or, even worse, fire-fighting can begin. Fire in wind turbines usually lead to a total loss of nacelle and rotor.

Damage by storm is not a problem worth mentioning (at least not in Denmark). There used to be two types of damage by storm: total loss due to a collapse of the tower, and loss of rotor blades and gearbox due to runaway spinning under extreme wind conditions. However, notwithstanding the constructional safeguards against storm made in modern wind turbines, the risk of damage by storm differs widely from one country to the next.

Damage caused by the wind turbine (liability) is very limited in scope as well as in number, the main reason being that wind turbines are usually sited in the countryside, far from populated areas, and therefore only rarely cause personal injury or damage to property.

Other types of damage in the above table include operating loss as well as short circuits in generator and control units and other types of minor damage, such as theft from the wind turbine, etc.

Claims series. Claims series also occur in relation to wind turbines, where a large number of cases of damage to wind turbines from the same production series can all be attributed to the same liability-entailing cause and, hence, be considered as one single insurance event.

This type of claim primarily involves damage to gear such as e.g. damage to the toothing or actual gear loss. Damage to rotor blades, too, may occur as part of a claims series.

6. Prevention of damage

Generally speaking, there are two ways in which insurers can play an active role in the prevention of damage. One is a direct role which consists of including provisions on precautionary measures in the insurance conditions, the other is indirect and consists of influencing the contents of approval and control schemes for wind turbines.

Both roles presuppose that, in addition to accumulating and systematically organising knowledge of and experience from claims and risk factors, insurers are also prepared to allocate resources which enable them to be more than generally updated with regard to technological developments in the field.

Basically, precautionary measures within the area of wind turbines are not much different from precautions known from other technical and mechanical areas, the main idea being to use experience, common sense and diligence in the design, manufacture, running and maintenance of the turbines.

It also applies to wind turbines that it is a question of always striking the right balance between, on the one hand, the wish for operational stability, safety and limitation of damage and, on the other hand, the wish for low production costs, low running costs and maximum performance.

Monitoring of operations

The experienced mechanical engineer knows that you need to listen to your machines. If a machine starts to sound differently, you need to locate the reason and put things right as soon as possible in order to avoid damage. This of course also applies to wind turbines, and some user manuals even state explicitly that you should listen to your wind turbine. However, due to the height of the tower and the generally remote sitings (sometimes offshore) it can be difficult to listen to the turbines regularly.

In consequence of this operations are monitored on a remote basis, with ongoing electronic transmission of the necessary data. Modern wind turbines have remote control and monitoring systems which allow the active remote control of turbine functions. Wind and weather conditions are monitored by two independent wind vanes, and remote monitoring is also made of generator, gearbox, yaw mechanism, temperature of high-speed bearing, oil pressure, vibration alarm and, of course, the power output. The monitoring signals are usually transmitted via a telephone modem to the computer of the owner or a service company.

Service and maintenance

Wind turbines should be subjected to minimum two annual service inspections to be performed either by a qualified service company or by the manufacturer. One inspection could be a lubrication check-up, while the other should be a comprehensive overhaul involving a control of all vital components, including a check-up of the insulation properties of the generator and the sampling of gear oil for an analysis of acid values and particle count. The oil analysis serves to determine the usability of the oil and reveal any signs of imminent pitting in the gear wheels.

In connection with the expiry of the manufacturer’s warranty period it is important for the owner of the wind turbine to get an overview of its state of maintenance in time for him to keep the deadlines stated in the warranty conditions for claims against the manufacturer. This control of the state of maintenance of the wind turbine should be performed by an impartial expert.

Direct prevention of damage

The most frequently occurring precautionary measures which producers, owners and insurers ought to take are the following:

Mechanical damage is best prevented by a demand for regular service inspections, the application of high-quality materials, competent operators, and equipment monitoring the turbine in operation. The most frequently occurring types of mechanical damage are caused by defective materials, fatigue, the use of the wrong oil or running at a wrong oil temperature, vibrations and overload. Remote monitoring and control systems should be able to stop the wind turbine in the event of failures. Also, the useful life of the turbine will be extended by a reduction of the operating load (or at least by omitting to increase the operating load).

Damage by fire is best prevented by the removal of all inflammable materials in the nacelle, wherever possible, and by limiting the sources of ignition, for instance by shielding the mechanical brake. The possibilities of detecting a fire in the initial stages will increase considerably if an automatic fire alarm system is installed. Moreover, it is possible to install a so-called dry irrigation system in nacelle and tower. This system can be designed with a connection to the pumps of the fire-fighting system.

Damage by lightning is prevented by protecting the rotor blades against lightning, i.e. by making sure that the electric charge of the lightning is diverted from the nacelle and taken straight to the turbine's foundation. Use of the most sophisticated lightning protection systems may reduce the risk of damage by lightning considerably.

Damage by storm is prevented primarily in connection with the design and construction of tower and rotor blades and by the application of automatic disc brakes. These are very effective precautionary measures, and this is clearly reflected in the claims statistics which show that damage by storm has not given rise to any major problems in Europe in recent years.

It is possible to effectively prevent the most elementary types of damage by the establishment of approval and control schemes. Similarly, quality assurance schemes, such as ISO 9000, help improve knowledge of the quality of the products.

At the national level insurer organisations may benefit greatly from active participation in the work done by national approval schemes, as is the case e.g. in Denmark with the Risø approval scheme. This enables the individual insurer to take account of an array of safety and technical factors when arranging the insurance merely be including a reference to specified national approval schemes, alternatively by reference to existing foreign schemes.

7. Certification and type approval norms

Public authority involvement in the regulation and actual legislation on wind turbines differs greatly from one country to the next. Suffice it to say here that regulation is used in connection with ownership, financial incentives, utility and grid-related issues, spatial planning, environmental protection, R&D programmes, the replacement of old wind turbines, and certification and type approval norms.

Of course several of these subjects may also be relevant to insurers, but in the following we will confine ourselves to dealing exclusively with some important issues in connection with certification and type approval norms.

In the 1970s, when the wind turbine was still in its infancy, there were neither national nor international rules or standards for wind turbines. Some of the very first wind turbines were of a very poor quality (insufficient calculations, poor materials, poor workmanship, etc.), and sometimes wind turbines collapsed or were felled by the wind. For safety reasons the public authorities in several countries therefore chose to draft guidelines or rules for the approval of wind turbines in an attempt to make sure that they did not constitute a hazard in their local environment.

One example of such a set of national approval rules is the Danish approval scheme for wind turbines.

The Danish Approval Scheme for Wind Turbines

In the late 1970s, the Risø National Laboratory was asked to draft a set of type approval norms for wind turbines installed with public investment grants. In practical terms this meant that wind turbines not approved under Risø's norms could not be installed. Today the 'approval market' has been liberalised and other test laboratories may obtain authorisation to issue type approvals and perform the necessary tests in connection therewith.

Bodies authorised to provide services under the Danish scheme for certification and type approval for wind turbines:

Service	Authorised body
Production and installation certification	Dansk Standard Germanischer Lloyds Certification GmbH Det Norske Veritas Certification of Mgt. Systems Bureau Veritas Quality Insurance
Type approvals	Risø, Approval Secretariat Germanischer Lloyds
Basic tests	Risø, Test & Measurements Tripod Consult Aps
Power curve measurement	Risø, Test and Measurements Tripod Consult Aps DEWI, Wilhelmshafen WindTest, Kaiser-Wilhelms-Kog GmbH
Noise measurement	DELTA Akustik & Vibration + bodies approved by DELTA DEWI, Wilhelmshafen WindTest, Kaiser-Wilhelms-Kog GmbH Wind Consult GmbH

Source: The Danish Energy Agency, „Wind Power in Denmark", 1998.

The Danish approval scheme was established at the request of manufacturers, owners, insurers and public authorities, and it builds upon technical guidelines – ”Technical Criteria for Type Approval and Certification of Wind Turbines in Denmark” – and on the ISO 9000 quality assurance scheme. The intention is for these rules to be replaced at a later date by similar standards from IEC or CENELEC.

The scheme for type approvals defines three approval classes: A, B and C.

To obtain an **A-Type approval** there must exist a production certificate and an installation certificate. Loads and strength/service life must be documented for all load-carrying components. Outstanding items are not allowed.

To obtain a **B-type approval**, production and installation certificates are required. The safety requirements are the same as for an A-type approval, but items judged to have no essential influence on primary safety may be listed as outstanding items to be documented after the approval is issued.

C-type approvals are used for test and demonstration wind turbines in connection with the development of a new wind turbine type.

The approval scheme is run by the Danish Energy Agency. An Advisory Committee has been set up with members drawn from, among others, the Danish Wind Turbine Manufacturers' Association, the Danish Wind Turbine Owners' Association, and the Danish Insurance Association.

The fact that Danish authorities managed to link together the possibilities of public grants, restrictive safety requirements and rather conservative standards for wind turbines at a relatively early stage meant that already in the early days of the 'era of the modern wind turbine' in Denmark it was impossible to install or sell low-quality and potentially dangerous products. Thus the worst kinds of teething problems were eliminated, and this was very positive not only to wind turbine owners, but also to Danish wind turbine manufacturers which, today, are leading in the world market. Danish insurers, too, of course benefited from the early introduction of the Danish type approval scheme.

8. Conclusions

The most central conclusions to be drawn from the present report can be summed up as follows:

- The deployment of wind turbines differs greatly in scope from one country to the next. Factors particularly important to the deployment of wind turbines are the possibility of the individual country to produce electricity by other renewable energy sources and the political will to create incentives for the promotion of wind energy in particular.
- National and international long-term objectives for environment and energy policies will lead to discernible growth in the number of wind turbines in the future (together with other renewable production methods).
- This will cause continued growth in the demand for wind turbine insurance in the years ahead.
- Although the fundamental wind turbine design is unlikely to change in the immediate future, there will still be considerable and rapid technological product development in the field for the purpose of reducing production and running costs while at the same time increasing the output of the individual wind turbine.
- Modern wind turbines are power plants and must be dealt with as such for insurance purposes.
- The siting of wind turbines (in remote areas and high above the ground) means that they cannot be dealt with in exactly the same manner as other machines/turbines in relation to insurance conditions, tariffing and damage prevention.
- National (and international) standards for wind turbines may determine the quality of wind turbines deployed in the individual countries, and insurers need to be acutely aware of this.
- Insurers may (at the national level) benefit from trying to influence the development and administration of national type approval schemes for wind turbines.

As our concluding and final remark we wish to point out that in this area, too, the experience/dogma applies that insurers failing to keep fully abreast of technological developments in this field should tread very carefully indeed.