



Danish Energy
Agency

QUALITY WIND

Improving
performance of
wind turbines



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THE QUALITY WIND PROJECT

China is the world's leading wind energy nation in terms of installed capacity and annual wind power investments, while Denmark is the world's leading wind energy nation in terms of wind penetration. Given China's and Denmark's internationally recognized positions as world leaders in wind energy, there is great potential for mutually beneficial cooperation.

Cooperation between the two countries dates back to 1989 when a Danish development project led to the establishment of China's first wind turbine power plant. Since then, two Sino-Danish wind and renewable energy programs have further contributed to the development of Chinese wind power.

The Quality Wind project (see textbox) builds on this long tradition of cooperation between Denmark and China and aims to increase awareness on how high standards for components and

maintenance affects the performance of turbines.

Denmark has decades of experience in optimizing wind turbine performance over the years. Major improvements in performance of newly erected turbines were achieved between 2001 and 2008 and onshore turbines erected since 2008 has reached an impressive 3,000 full load hours - equivalent to a 50% jump in production compared to older reference groups. But equally important, Danish experience shows how performance can be kept at a high level year after year.

In Denmark even 24 year old turbines still deliver approx. 1,900 full load hours each year, which corresponds to the theoretical performance for this generation of turbines. Good quality turbines and components, and high standards for service and maintenance are the

reasons why these turbines are still performing according to their expected theoretical performance. This publication will describe how the Danish legal framework, educational programs

ensuring skilled technicians as well as a systematic and professional approach to maintenance among Danish turbine owners have contributed to the high performing wind turbine fleet.

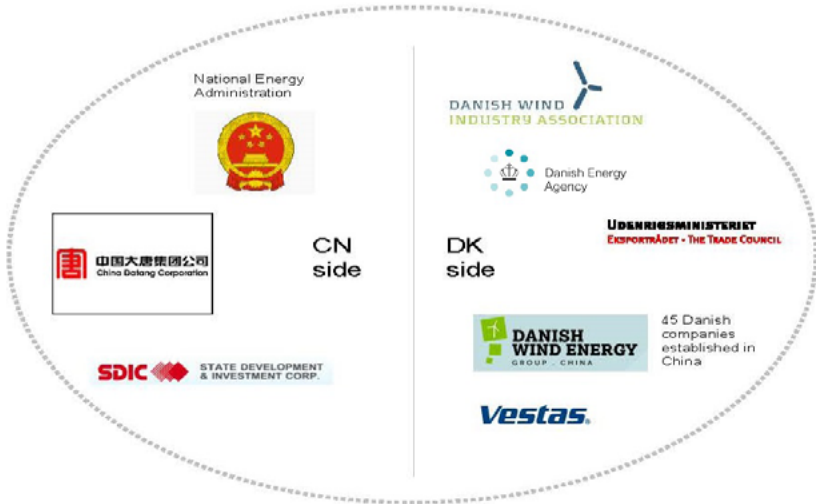


Figure: Stakeholders in the project

FACT BOX

Two of China's most innovative wind developers, Datang Renewables and SDIC, are participating in the Quality Wind project to investigate the potential for improving the performance of existing turbines in China. Their willingness to investigate how innovative technologies and best in class operation and maintenance can enhance performance even further and reduce cost of energy is crucial to the project.

Datang Renewables and SDIC are currently exploring the opportunities for commercial cooperation with Danish suppliers of technology and O&M services. It is expected that cooperation will result in an increase of full load hours with an acceptable payback time to the Chinese investors. The Danish Energy Agency and China's National Energy Administration are facilitating the cooperation and when successful DEA and NEA will explore how the experiences of the Quality Wind project can be applied on a larger scale in China.

INVESTMENTS IN MAINTENANCE OF WIND TURBINES IN DENMARK SECURES HIGH AVAILABILITY

Investments in high quality wind turbines and efficient Operation and Maintenance (O&M) enables Danish turbine owners to achieve an availability of turbines that is usually between 97-99%.

This level of availability is indeed an impressive result. A wind turbine on a good site in Denmark will, in a normal year, produce electricity for 6.500 hours which means that the turbine is producing 75% of the time. As modern turbines are constructed to be in operation for 20 years the turbine will be producing for approx. 130,000 hours in its lifetime. During the 20 years the

main shaft will have rotated about 200 million times. To put it short, the stress on the construction is far more than what most other machines experience in their service life.

FACT BOX

On average onshore turbines in Denmark can produce electricity for 6500 hours during the course of the year. Because wind speeds vary, the turbines will not be producing at maximum capacity for the entire 6500 hours. The total production achieved during the 6500 hours is equivalent to 3,000 full load hours meaning that if the turbine was always operating with maximum output it would take only 3000 hours to reach the annual level of electricity production.



For instance, a car will drive about 300,000 km in its lifetime. If the average speed is 60 km per hour the car will have been running for merely 4,500 hours when it reaches the end of its service life. A turbine will have been running 4,500 hours within the first eight months of operation with the wind regime known in Denmark.

The heavy stress on wind turbines means that great care should be taken to minimize production loss resulting from fatigue of components. To achieve this goal wind turbine owners should implement more than simply corrective maintenance to rectify faults that has occurred.

Preventive maintenance should be carried out regularly to secure that wind turbines are in satisfactory operating condition. Preventive maintenance means systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects. Optimal timing of maintenance can be achieved by using ongoing monitoring of turbines to enable predictive maintenance. Vibration analysis of major components such as gear boxes and analysis of size and number of particles in oil and grease are examples of monitoring activities that can enable turbine owners to secure optimal timing of maintenance.

The Danish Wind Turbine Owner's Association estimates that the total cost of insurance, O&M, replacement of defect components will accumulate to approximately €0.8-0.9 cents per kWh produced over a period of the 20 years of service for turbines above 1 MW. According to the Danish Wind Turbine Owner's Association the norm in service contracts in Denmark is to have inspections between one to four times every year. Yet even with proper service turbines owners can experience considerable expenses to repairs of normal material wear and fatigue related damage of the main component such as the generator, gears, wings etc.

Owners can expect to use 20-30 % of the cost of the turbine on repair of these damages on top of normal O&M cost. Still the investment in O&M and replacement of defect components are deemed necessary by owners in Denmark to optimize the business case of the owners' wind assets.

LEGAL FRAMEWORK SUPPORTS HIGH PERFORMANCE IN DENMARK

Following the collapses of two wind turbines within the course of a week in 2008, the Minister at the time, called for an investigation to determine the cause of the two wind turbines collapse. The incidents followed other breakdowns both in Denmark and in other countries that were reported in the press in the previous two months.

The Minister made a statement in a national newspaper stating that the problems with the turbines abroad had to do with poor maintenance, and if that was the case in Denmark, the problem with lacking maintenance had to be rectified. As a result of these incidents Denmark implemented an Executive Order on a technical certification scheme for wind turbines which entered into effect in the same year. The Executive Order stipulates that owners of wind turbines are responsible for ensuring that the wind turbine is maintained and serviced at least every two years for as long as it is in operation.

The maintenance and service of the wind turbine must be performed according to the specifications and time intervals for regular service of the turbine as stated in the certificate issued or service manuals prepared by the manufacturer. If the owner of wind turbines fails to comply he will be forced

to stop production from the turbines.

The Danish Energy Agency is the responsible authority but the daily operation and responsible of the scheme is the Technical University of Denmark, which is currently appointed as the Energy Agency's Secretariat for the Danish Wind Turbine Certification Scheme.

SERVICE COMPANIES MUST BE CERTIFIED

For wind turbines with a rotor area of more than 40 m², maintenance and service is performed by a certified company. Certification can be issued by an accreditation company recognized by the Multilateral Agreement of the European co-operation for Accreditation, the Danish Energy Agency or the Secretariat for the Danish Wind Turbine Certification Scheme. The owner of the turbine can also carry out the required service of turbine with a swept area of less than 200m² if the owner can provide documentation for relevant training and adequate knowledge of maintenance and service of the turbine in question.



Photo: www.stateofgreen.com

A certified company is only certified for specific types and sizes of turbines and can only carry out service for these types and sizes of turbines. To obtain certification a service company must provide the following to the accreditation company:

- Documentation that the company has adequate experience and expertise within the field of wind turbine maintenance and service, and has implemented a quality management system according to ISO 9001:2008 or similar. Sub suppliers must also be included in the service company's ISO certification and instructions.
- Documentation that service manuals for the relevant turbine types, as well as updates that affect the operation of the wind turbine are available to the service company.
- Documentation that the required tools are available to the service company.

The certified companies will be audited once a year and the following is in focus:

- Random controls to check that maintenance and service of the turbine have been performed as described in the service reports.
- The company has up-to-date service manuals for all of the wind turbine types on which the company performs services;
- If the manufacturer no longer updates the manual, the service company must itself supplement the service manual with the changes and improvements introduced by the service company;
- Service reports for each service visit are available in accordance with the service agreement entered into between the owner of the wind turbine and the service company;
- Maintenance and service are performed by qualified personnel in accordance with the up-to-date manuals and the specified intervals for maintenance and service;
- As required, a completed check list is available with documentation for the operational conditions of the wind turbine in accordance with the manuals for maintenance and service;
- Any repairs and changes to, and replacements of, components have been performed in accordance with current service manuals.

RESPONSIBILITY AND REPORTING

It is the responsibility of the manufacturer/supplier to deliver the necessary service manuals to the owner of the wind turbine upon delivery of the wind turbine itself.

Updates of significance for operation of the wind turbine must also be forwarded on request by the owner of the wind turbine. This also applies to service companies that make modifications to the wind turbines; they must incorporate their modifications in the owners' as well as in their own service manuals.

A service report is prepared at each service visit and submitted to the owner of the wind turbine. The owner of the wind turbine must store the service reports for as long as the wind turbine is in service. Furthermore, the owner of the wind turbine must report completed service and the date of the next service to the Danish TSO, Energinet.dk.

In the event of major damage or damage affecting safety, the owner of the wind turbine shall immediately submit information about the event to the Energy Agency's Secretariat for the Danish Wind Turbine Certification Scheme.

Major damage and damage affecting safety could include turbine shutdown due to risk of breakdown; blades or blade components that fall down; other components that fall down and damage resulting in fire or in the blades running wild.

Reporting is to ensure that knowledge about such damage is collected, so that the Secretariat for Approvals can assess the need to launch investigations as well as the need for updates to the scheme's technical basis.

Service inspection of wind turbines that have been in operation for longer than their design lifetime must, in addition, cover an inspection and assessment of the wind turbine's structural parts in relation to the turbine's continued operation.



EXAMPLE

On 29 November 2011 and 24 February 2012 two 200 kW turbines that had been in operation for 22 and 24 years respectively (NB expected life time of the turbines is 20 years) fell over. After inspection it was concluded that the cause was defect flanges, bolts and welding. The Secretariat for the Danish Wind Turbine Certification Scheme requested all owners of this type of turbines to perform an extraordinary control and service of their turbines within three months.

A total of 44 turbines were still in operation at the time. Of these the inspections resulted in the following preventive repairs:

Inspection of	Total numbers of repaired turbines
Tower bolts	14
Foundation bolts	13
Tower and foundation bolts	7
No remarks	19
Turbine unmounted	1

SKILLED WIND TURBINE OPERATORS ENSURES HIGH QUALITY

By Jesper Hvilby Ulrich, Educational Consultant at the Secretariat of Industrial Training

Denmark has decades of experience in turbine manufacturing and maintenance and skilled workers ensures high quality in the Danish wind industry.

It takes two years to complete the industrial training as wind turbine operator in Denmark. The education includes both practical training in relevant companies and training at a technical school and enables the workers to undertake positions within production as well as service and maintenance of wind turbines.

To ensure that the wind turbine operators have high qualifications within both production and maintenance of turbines the students choose to specialize in either hydraulics, electrical parts, cables and wires relevant for production of the nacelle or casting processes, composite mold construction, glass fiber, finishing and repair relevant for the production of the blades.

It is important that the wind industry has employees that are independent and can take responsibility and contribute to quality improvements. The staff in production and maintenance is crucial for ensuring high quality of Danish turbines and hence the training as wind turbine operator is relevant to many, says Elise Andsager, training consul-

tant at The United Federation of Danish Workers and member of The Committee for Development of Wind Industry in Denmark.

NEED FOR SKILLED WORKERS

The training program for wind turbine operator was established in 2007 as joint cooperation between the The Confederation of Danish Industry, The United Federation of Danish Workers and representatives from the wind industry. All parties wanted to ensure that the Danish wind industry always has access to skilled workers. The training program is funded and closely monitored by the Ministry for Children, Education, and Gender Equality.

To ensure high quality in production, maintenance and service of turbines it is important that the companies can recruit qualified and competent workers. Highly skilled workers ensure a competitive wind industry and it is important that all stakeholders contribute to the development of the training of workers, says Christine Bernt Henriksen, senior advisor at The Confederation of Danish Industry and member of The Committee for Development of Wind Industry in Denmark.



The Danish wind industry contributes with knowledge and input to ensure that the training is continuously improved to ensure the highest possible quality. Vestas Wind Systems and Siemens Wind Power actively participate in the development and are among the companies that offers practical training to apprentices.

HIGH QUALIFICATIONS ARE IMPORTANT

The training program is designed to ensure that students obtain the necessary qualifications. The training focus on quality and product optimization, documentation and lean processes. Furthermore, all wind turbine operators

must be certified in first aid, firefighting, welding and working with epoxy. The training is always in line with the newest occupation, health and safety standards.

After two years of training all students are tested for their proficiency at a final exam. Examiners from the wind industry evaluate their qualifications and skills. If the apprentices pass the test they are awarded a certificate proving that they are now skilled wind turbine operators.



LIST OF DEVELOPERS

List of Danish companies supplying components and solutions to the Chinese market

- Aluwind Guangdong Windpower Co., Ltd
Aluminium solutions www.aluwind.com
- Arvind Nilsson
Special bolts/studs/nuts www.arvidnilsson.com
- Awanti Wind Systems A/S
Service lift, fall protection www.avanti-online.com
- Bach Composites Industry A/S
Composite components www.bach-ci.com
- Blue Water Shipping
Logistic www.bws.dk
- C.C.JENSEN Filtration Equipment Co., Ltd.
Filtration System www.cjc.dk
- DAFA A/S
Seals, Insulators, Protectors www.dafachina.cn
- Danfoss Automatic Controls Ltd.
Cooling, Heating, Industrial automation www.danfoss.com
- DEIF A/S
Controller System www.deifwindpower.cn
- Dialight BTI A/S
Obstruction lighting and aids www.bti-as.dk
- DSV A/S
Project transportation www.dsv.com
- EIPRESS
Electrical connection www.elpress.com.cn
- Eltronic A/S
Eltronic Tracking Device www.eltronic.dk
- Force Technology (Beijing) Co., Ltd.
Consultancy and inspection www.forcetechnology.com
- Fritz Schur Energy A/S
Hydraulic and pneumatics www.fsenergy.dk
- FT Technologies
Acoustic resonance air flow sensors www.grene.com

- Gis (Tianjin) Service & Technology Co, Ltd.
Tools www.glps.dk
- Global Lightning Protection Services A/S
Lightening protection www.granudan.com
- Granudan ApS
Release coating www.grenaahavn.dk
- HEMPEL (China) Ltd.
Coating www.hempel.com.cn
- Hove A/S
Grease and pumps www.hove-as.dk
- Hydratech Industries
Pitch, Brake, Hydraulics and Cooling www.hydra.dk
- Hydra-Grene A/S
Lubrication, Cooling, and filtration systems
com www.hydratech-industries.com
- Jupiter Group A/S
Composite components www.jupitergroup.dk
- K2 Management A/S
Consultancy business www.k2management.eu
- KK Wind Solutions
Wind turbine controller www.kkwindsolutions.com
- M Seals A/S
Seals www.m-seals.dk
- Mecal Denmark ApS
Turbine Design, Due Diligence,
Inspections, Offshore/ onshore consultancy www.mecal.eu
- Megatrade Beslag (Shanghai) Trade Co., Ltd.
Accessories www.megatrade.dk
- Mita-Teknik
Controller Systems www.mita-teknik.com
- Nibe Wind Components
(SAN Electro Heat, Jevi & Danotherm, L&S)

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|---|--|
| Electrical heating | www.nibewind.com |
| ■ Niebuhr Gears (Tianjin) Co., Ltd.
Gears | www.niebuhr.dk |
| ■ Nissens A/S
Cooler | www.nissens.cn |
| ■ NMF Mechanical Production Co., Ltd.
Aluminium platforms | www.nmf.cn |
| ■ PMC Technology
Hydraulics | www.pmcqingdao.cn |
| ■ Resolux
Lighting for tower, nacelle and hub | www.resolux.dk |
| ■ Rimadan (Ningbo) Mechanical Engineering
Manufacturing Co., Ltd.
Precision products, consultancy and
site management services | www.ah-industries.com |
| ■ RMG Steel Co., Ltd.
Steel and aluminium components | www.granly.dk |
| ■ SSP Technology
Blade Design | www.ssptech.com |
| ■ Windar Photonics A/S
Lidar System | www.windarphotonics.com |

The Danish Energy Agency's Centre for Global Cooperation supports emerging economies to combine sustainable future energy supplies with economic growth. The initiative is based on four decades of Danish experience with renewable energy and energy efficiency, transforming the energy sectors to deploy increasingly more low-carbon technologies.

Learn more on our website:

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