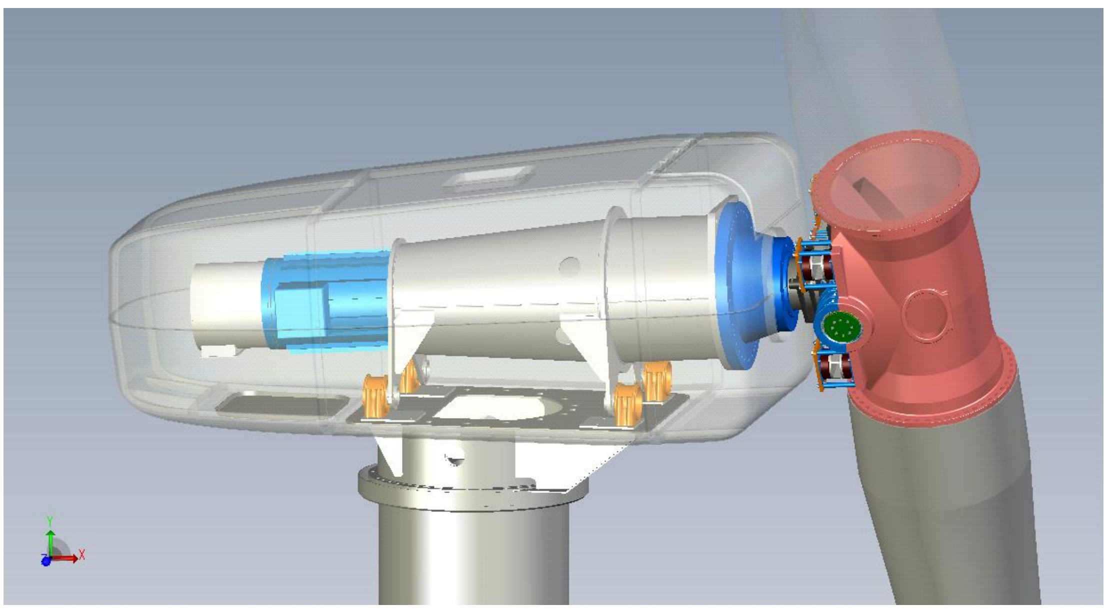
Arguments for large two-bladed wind turbines

Adapted from NORDIC WINDPOWER AB 2001-01-17 Staffan Engström

Overview

Nordic Windpower has designed a two-bladed, utility scale wind turbine that overcomes earlier problems with two-bladed turbines and which provides the cost and performance benefits of the two-blade configuration. Two blade configurations have in the past experienced higher fatigue loads and noise problems. The Nordic Windpower N1000 uses a damped teeter hub and a modular drive train configuration that effectively dissipate fatigue loads. Tip speeds are regulated such that the turbine has lower overall noise than three blade turbines. The turbines running for up to 10 years have had no major component issues.



Technology and Economy

A wind turbine generator extracts energy from the wind by reducing the speed of the wind and therefore the energy in the wind. For a wind turbine of a certain power, diameter and rotational speed, a certain total area of aerodynamically active surfaces is needed in order to achieves a specific wind braking effect. The majority of today's wind turbines utilize three blades. However, if the necessary blade area instead is distributed on just two turbine blades, a number of advantages will be achieved. The primary effect is that the blade chord ("blade

Nordic Windpower LLC
mailbox: 1537 Fourth Street #147, San Rafael, CA 94901
tel: +1 415 887 7628   toll-free: 888 322 2080 fax: +1 775 201 8500
www.nordicwindpower.com

width") increases. Since a blade profile is characterized by its relative thickness (blade thickness to blade chord ratio, normally 15-20%), this means that also the blade thickness increases with increased chord. A consequence of the thicker blade is a considerable increase in strength, since the strength of a beam is proportional to the third power of its height. This decreases the need for structural material, which makes the blade relatively lighter and cheaper. Since this is in addition to the decrease in the number of blades needed, the total blade cost is significantly reduced. See Fig. 1.

Another significant advantage is that it is much easier to handle a two-bladed wind turbine during the erection procedure, since the blades may be mounted to the nacelle on the ground. A three-bladed turbine has to be lifted separately and mounted to the nacelle when on the tower.

Under the same general conditions, the two-bladed turbine is slightly less efficient than the three-bladed. The difference in the yearly energy production is around 2-3%, which may be compensated by a 1% increase of the turbine diameter. Thus, this is no argument against the use of two-bladed turbines. See Fig. 2.

The reason for the current dominance of the three-bladed wind turbines is rather that a two bladed wind turbine is significantly harder to design, which is a consequence of its asymmetry, whereas the three-bladed turbine is symmetrical. Due to the very complex calculation interrelations, the access to a comprehensive and easy to use simulation computer program is a necessary prerequisite for exploiting the advantages of the two blade technology. Nordic Windpower operates such a program that has been developed in the Swedish wind energy research program since the early l980's. In addition, Nordic has ten years experience in designing two-bladed wind turbines.

Another necessary prerequisite of a successful two-bladed wind turbine is a teeter hub, which means that the hub and blades are hinged to the turbine shaft. Although the range is quite small (+/-2 degrees), this motion has a decisive influence on the loads acting on the wind turbine system. Nordic Windpower has developed teeter hubs that have been in continuous operation since 1992.

These technical arguments for two-bladed wind turbines have long been known to the wind power community, and they were why the Swedish National Wind Power Program in the 1970's concentrated its efforts on the two-bladed technology. At that time however the companies involved did not master the technology because the necessary computer codes had not been developed. In many cases this resulted in technical problems, and this is why most commercial producers have implemented the less demanding three bladed technology.

The Nordic Windpower one-megawatt turbine has demonstrated experience to show that the design implements these solutions. Turbines have been running for up to 10 years with no operational issues in the gearboxes, blades, hub, drive train or any major component.

The Nordic Windpower design utilizes these major design features for successful two-blade implementation:

- A teeter hub with damping that dissipates blade forces before they reach the gearbox.
- An integrated drive shaft and gearbox that allows for much more robust bearing configuration.
- A single unified, tubular housing for gearbox, drive shaft and generator to hold steady this system and allow forces to dissipate away from the gearbox.
- Cooling for gearbox and generator sufficient to keep oil temperatures well below critical.
- Many other innovations to reduce maintenance and increase reliability.

The Nordic Windpower wind turbines are related in engineering details to the 3 MW two-bladed WTS3 wind turbine which was developed in co-operation between Swedyards and Hamilton Standard, with experience from rotary wing aircraft etc.. It experienced no major component problems and was operated between 1982 1993 at Maglarp in south Sweden until it was demolished for research purposes while it was still in great operating condition. Even today this wind turbine has the world record for wind energy production at 38 GWh.

Offshore Wind Power Advantages

Wind turbines sited on land are usually limited in their power production by their noise output determined by the blade tip speed and hence rotational speed. By siting wind turbines off shore this restriction is lifted. Two-bladed turbines benefit more from this parameter change than three-bladed turbines. The 50% larger chord and attendant greater structural strength of the blades allows an increase of the tip speed to substantially larger values than those that are possible with three-bladed turbines. This is of great importance, since the cost of the gear box or direct drive generator is inversely proportional to the rotational speed leading to further cost reductions.

The need for large units and the easier handling of the two-bladed turbine are additional reasons many experts forecast that two-bladed turbines are likely to dominate the future offshore market.

Improved Visual Appearance

The experience of the general public of two-bladed wind turbines is mainly related to small units. A small wind turbine will have a high rotational speed, irrespective of the blade number, since any wind turbine is designed for a certain blade tip speed, which makes the rotational speed inversely proportional to the turbine diameter. For a small two-bladed turbine the high rpm has the drawback of making the rotation appear irregular, which disturbs most people. However, this impression disappears with increasing turbine size and decreasing rotational speed. The argument regarding the visual impression was not expressed in connection with the former Swedish large wind turbines at Maglarp and Näsudden, neither regarding the Nordic 1000. By coincidence, the Nordic 1000 has the same rotational speed as the larger Maglarp and Näsudden units. This is due to the need to reduce the noise. Nordic Windpower has video available to illustrate this point.

The visual experience of rotational speed differences is primarily connected to the frequency of blades passing by the tower or to the horizon. At the same rotational speed, the blade passage frequency of a two-bladed turbine is just 2/3 of the value of a three-bladed turbine. This may be why large, two-blade turbines appear calmer. To some, the large two-bladed wind turbines look more majestic.

Equal or Less Noise

For onshore wind turbines in habited areas the acceptable blade tip speed, and thus the rpm, is determined by noise restrictions. Therefore today's two-bladed wind turbines are designed for the same tip speeds as three-blade turbines. This will even result in slightly less noise, say 1 dB, than for corresponding three-bladed turbines. With a lower number of blades the total noise producing surfaces are reduced.

Shadows

The shadow from a wind turbine hitting a building's window results in a periodical and annoying variation of the lighting conditions inside the room. A Swedish governmental investigation (Vindkraftsutredningen, SOU 1999:75, p. 101) mentions an annual cumulative shadow time of 10 hours as being acceptable to inhabitants. This factor may become increasingly important in the future, since the generally less noisy wind turbines are placed closer to buildings will make the shadow conditions important in determining acceptable distances to adjacent habitation. The two-bladed turbine have a shadow frequency, which is 2/3 of that of a corresponding three-bladed turbine.

Arguments for Large Two-Bladed Wind Turbines

- A wider chord is advantageous for the blade structure.
- A considerable reduction in turbine cost.
- A reduction in production of 2-3% may be compensated by a 1% increase in turbine diameter.
- Easier handling during erection.
- Especially advantageous for offshore windfarms.
- A comprehensive computer simulation and a teeter hub are required.
- Small two-blades looks jerky.
- Large two-blades give a majestic impression.
- Slightly less noise than a corresponding three-blade.
- Disturbance from shadows may be less.

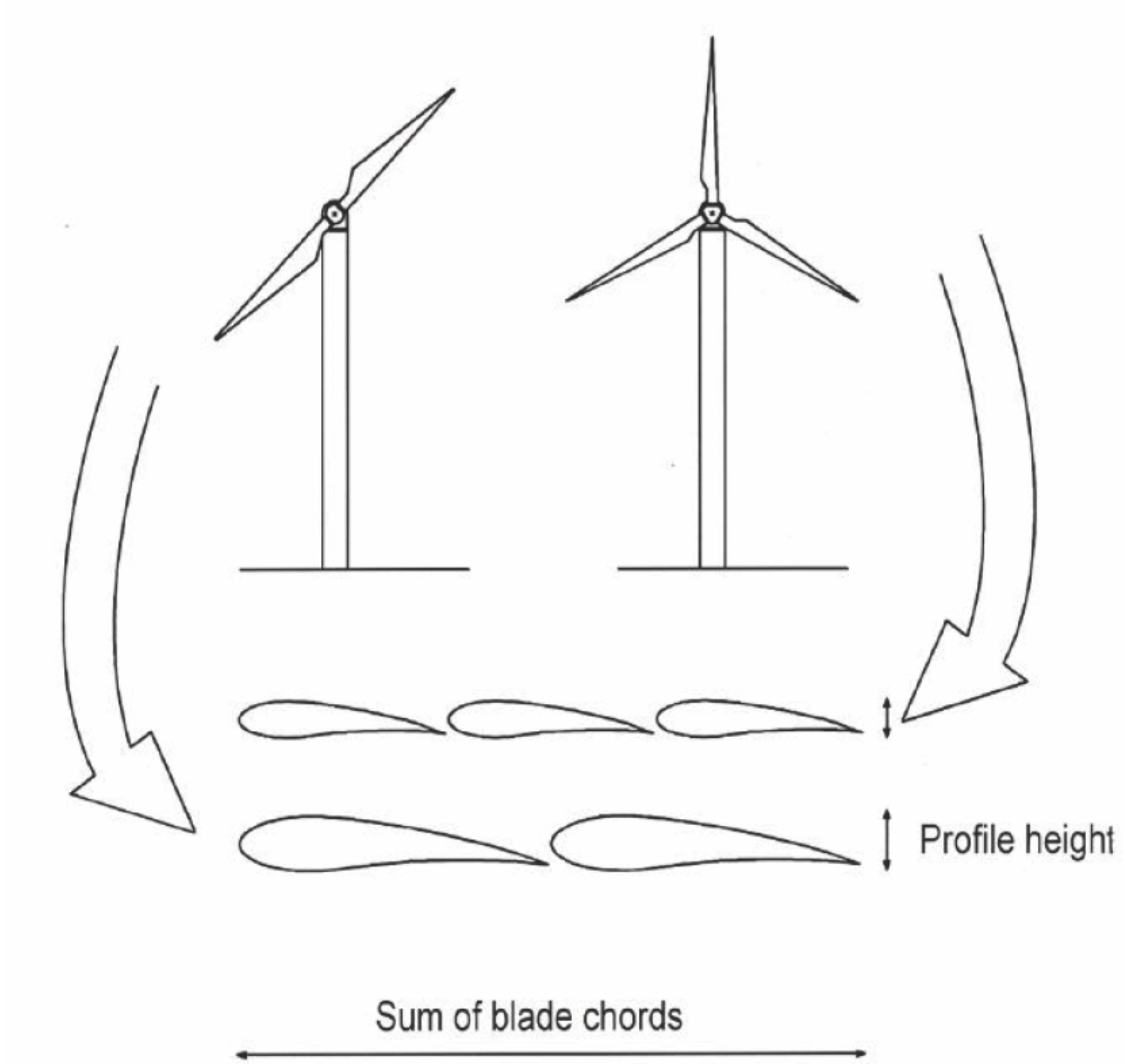


Figure 1. Blade chord and profile height for two- and three-bladed wind turbines of equal power output.

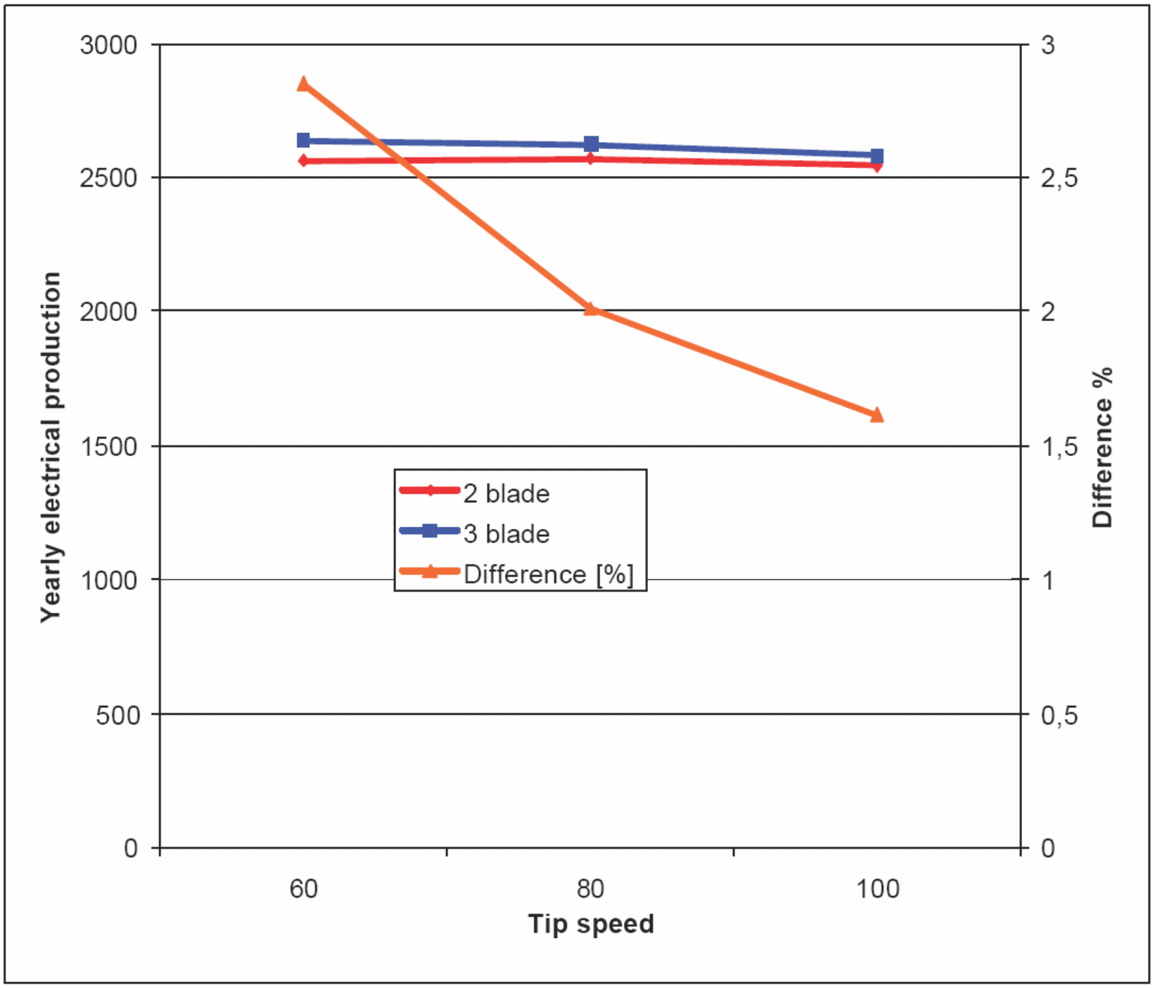


Figure 2. Yearly energy production from optimised two- and three-bladed wind turbine systems.