ADVANCES IN WIND TURBINE DEVELOPMENT

Carl-Erik OLSEN

WIND TURBINE DEVELOPMENT – LOOKING BACK

The modern and automatically operated wind turbine is now more than 20 years old, but mankind has made exploitation of wind energy for centuries. Successful experiments with wind powered electricity was actually carried out in Denmark as early as 1891, and the first stall regulated and grid connected wind turbine began operation 44 years ago.

Through the years Research & Development focus has changed. It was relatively easy to get the wind turbine to produce power using an asynchronous motor and operate it as generator. At first the major concern was to control the power output and avoid overproduction in high wind as well as having sufficient safety and brake systems. There were problems in getting the early blades to last and to learn the aerodynamic behaviour of the blade profiles 3-D operation. The rotor blade profiles used were based on thorough measurements and tests of aircraft wing sections, which all operate in a two-dimension world only. The extra dimension was and still is a big challenge! Later, high efficiency as well as the right level and time of power control became a dominant priority. In the beginning the majority of Danish manufactures used stall control. Later power control by pitching the blades was introduced and the gain was other problems to solve. What ever you do, you have a gain/loss situation. Apart from the blades the wind turbine manufacturers at first purchased off-the-shelf components from sub-suppliers and designed the wind turbines on basis of available experience. Grid quality was becoming an issue as well, and more sophisticated technologies were introduced like variable rotor speed and high complex power electronics. Actually variable speed is a must for pitch controlled wind turbines to reduce stress from wind peak loads. Still most of the designs looks the same, and no technology has proven to outperform any competitors, except that all survivors of today have 3-bladed, up-wind placed rotors, active yaw system and grid connected wind turbines. Regardless the kind of power controlling technology used the different wind turbines are remarkably equal in price per produced kWh annually. And stall controlled machines with dual rotor speed are just as efficient pr. square meter rotor disc as pitch regulated variable speed counterpart. Surveys show this fact very clearly. More important, wind power has now become competitive with conventional power production, which use fossil, hydro or nuclear energy.

Above all there were always economical considerations. Cost efficiency and profitability to all players, wind turbine maker, developer, owner and operator. Going hand-in-hand with energy prices, interest rates, demands in power capacity, industrial growth, creation of new jobs, environmental concerns, all fuelled by political initiatives.

ADVANCES IN COST REDUCTION

As production numbers have increased the sub-suppliers have accepted to manufacture more specialised components exclusively designed for wind turbine application. Through the years wind turbines have grown bigger in size and capacity, and along the road they have become more cost efficient. Here, the development of more efficient mechanical equipment or more refined rotor blades has the least contribution. The major achievements have been through thorough and ongoing measurements and introduction of wind turbine simulation computer programs followed by full-scale verifications, all to learn more about what is actually going on during operation. Astonishing growth in market and sales giving bigger production numbers, sub-suppliers parallel development, the supply of components specifically made for wind turbines, all have contributed to make the machines much more cost efficient. Considering the nacelle weight including all components (excluding rotor and tower): during the last 8 years the typical nacelle weight related to the swept rotor area has gone down from 16 kilogram per square meter to 12 kilogram or even slightly less. This is a 25% reduction in component weight alone. The greater production volume calls for another 10-15% manufacturing cost reduction.

However, the ongoing optimisation of wind turbines makes them more sensitive to variations in wind regimes and climate conditions from site to site or country to country. Nowadays average or standard wind turbines, which earlier could be placed nearly anywhere, do not exist any more.

SITE CONDITIONS

Having wind turbines installed all over the world means a great variety of site conditions. From normal climate to arctic or tropical conditions; low, medium or high wind regimes; small or great density variations; grid quality and requirements; environmental concerns, regulations forced by government and local legislation or civil aviation administration all have influence on wind turbine designs and chosen technology.

The consequence is that some wind turbines are more “adaptive” to a given site than others or the maker’s choice of technology has a small lead. But very often, during a competition race to gain a project, a supplier stresses or claims his technology to be superior to others without actually having any significant difference or advantage in the specific project.

NEG MICON PRODUCTION RANGE

Before mention NEGM’s advances in technology we must have a look at the production range. Through the last six years 3 dominant wind turbine platforms have emerged in NEGM. Each type has its own market possibilities. The platforms were originally developed to carry wind turbines in the 600-750 kW class, 1.0 MW class and 1.5 MW class, but each of them have been subject to sizing-up and borrowed advantages from each other. The target is to optimise the rate of utilisation in each class, adapt to the different market demands and site conditions, and exploit the given platforms to their ultimate limits. Still without endangering the prescribed and reasonable safety factors.

The platform size is like a cost frame. The bigger platform, the higher costs of manufacture, shipment and installation. Therefore, it is important to get the most out of each frame. The 600-750 kW platform now carry 900 kW, the 1.0 MW platform has turned into 1.5 MW, and the biggest platform is now a 2 MW wind turbine. And it is not just a bare increase of capacity; the respective rotor discs have been scaled-up vastly as well.

An extensive measuring campaign to know and verify fatigue loads and stress concentration is the key to do make such a development. But also the introduction of new technology regarded in a wider perspective has.

ADVANCES IN 900 KW DEVELOPMENT

The old 600-750 kW platform was fabricated in steel. Now the main platform part, which carries the rotor shaft and gearbox on top of the yaw system, is of cast steel. Using this way of manufacture a considerable material optimisation has been made, superior to a welded steel construction. Further, the yaw system has been integrated and completely redesigned into a totally closed and permanently greased system.

The major advantage is that the overall dimension is the same, it is easier to mill during manufacture, and it can handle about 60% more load than the previously welded steel type. Further, assembly costs are reduced. The 900 kW is completely outperforming the old 600-750 kW wind turbine.

Experience of the 20-t platform has been gained through operation in many different climates and countries as representing the biggest and easiest wind turbine to ship anywhere in the world. Where a truck can go, it can be installed. On top of that it is a simple, efficient and highly reliable machine. For many years to come we expect it to be an essential and dominating power plant for export.

ADVANCES IN 1.5 MW DEVELOPMENT

The platform was born 6 years ago as a cast steel design for 1 MW and 60-m rotor just as the later 900 kW. It is now slightly modified to adapt the rotorshaft and gearbox arrangement of 1.5 MW and 64 m rotor. But recently we have gone even further making a low wind regime version borrowing an active stall rotor design of 72-m from the bigger 2 MW platform.

ADVANCES IN 2 MW DEVELOPMENT

Our first 2 MW with 72-m active stall rotor was installed about 2 years ago. More than 20 units have followed. Valuable measurements and load verifications have been carried out, and we are now preparing its successor with 80-m rotor. But it will not be just an up scaling. Originally the platform was fabricated steel. Now we will cut costs further in the process by designing a cast steel platform as known from the other and smaller wind turbines.

ADVANCES IN TECHNOLOGY

What is “advances in technology”? Some would say new technology as to improve the design, abandon old ideas and introduce new ones. But the way of wind turbine development has always been small steps using the predecessor track record and boost up the size. Another advancing way has been to use the newest technology in manufacturing, improvements in components and computers. Not only directly in the wind turbine controller, but also through design, calculation, 3-D drawings, measurements and verification. And the installation costs in relation to power production abilities have dropped step by step. This is the real target. Some consider fixed speed stall rotor wind turbines to be old-fashioned. True, the idea was first used in 1957. But it works fine; it is efficient and simple. How about variable speed and pitch regulations of power output with frequency converters. That must be an improvement. Not necessarily, the system does not increase annual power production, it is definitely not cheaper, and it just adds complexity to the wind turbine and possibly service and maintenance costs as well. But the power and grid quality is improved? Both yes and no. Yes, to some extend on weak remote grids power control can have an edge. But as long as the grid is able to distribute power from a farm of 10-20 units the high technology wind turbines have no significant advantage. But the power electronics add harmonic distortion to the grid, which is most undesirable. However, stall has a drawback: in the winter, when the air density is higher, the stall rotor has a relatively higher maximum output. Therefore some manufacturers have introduced a pitch/stall concept. The blades are mounted on bearings to the hub, with independent hydraulic operation. The advantages are

- Securing the advantages of stall
- Smooth grid connection at all wind speeds
- Power control by active stall in high wind
- Reduced loads at standstill in extreme wind conditions
- No power electronics and harmonic distortion of the grid

In general, the ability of annual power production is a question of actual power loading of rotor disc area and the site wind distribution. Not the manufacturers name on the nacelle. The wind turbine maker's choice of technology makes no significant difference. Still some wind power plants are more adaptive to the specific site than others, and this makes a small and changing edge in competition.

FUTURE STEPS AND CONCLUSION

The market is growing as the demand for power capacity is. Wind turbines will play a greater and greater part of the electrical power picture, fuelled by environmental concerns to avoid carbon-dioxide pollution. New sites and grid requirements will show up, and the wind turbine makers will adapt their design accordingly. New steps will be taken and the costs of power through wind energy conversion will continue to decrease slightly.

There is no distinct picture showing that one wind turbine technology is superior or outperforming others. All players are improving their designs with success and competition is strong. Advances are made in very many different aspects, and is not just a question of new ways of wind power controlling technology.

The power production prices are now competitive with conventional power plants, but wind turbines are still unable to operate in large scale without the grid and its stable frequency support.

So there is still room for new developments.

Thank you for your attention.

ABOUT THE WRITER

One of the pioneers of Danish wind turbines. He has been working with wind turbines for more than 20 years within development and manufacture of rotor blades and wind turbines. He has been involved in marketing and sales as well as managing installation and service of wind turbines world-wide. To day he is providing technical information from Research & Development to support sales, marketing as well as the carrying out general technical introduction and education at all levels.