

# WIND TURBINE TECHNOLOGY

## Risks and innovation

The first wind turbines were developed over two thousand years ago as simple vertical axis water pumping devices in the Middle East. In 1066 AD there were more classic windmills in the UK than there are modern wind turbines today. In the last century wind turbines have progressed from what was not much more than a water pump with a generator attached to farm buildings - to fully fledged large scale commercial energy producing power plants.

The sizes of some of the offshore and onshore wind farms that are being developed today are comparable with current electricity production plants. For example a modern onshore wind farm such as Whitelee or Clyde can produce about 300MW of power and when they are fully developed will be rated at over 500MW each. Wind farms such as Thanet generate 300MW and the London Array when completed next year will be rated at 640MW compared to a typical large UK nuclear (Hinkley B) power station delivering about 840MW and a large coal fired power station yielding 2,000MW (Longannet) or 4,000MW (Drax).

Wind power as commercial energy generation is still in its infancy in terms of harnessing this resource with potentially much development still to be done. Whilst nuclear apexes its own technology, future expertise and development are already moving to offshore wind as a major contributor to our energy requirements. As such wind energy is now widely accepted as a central part of the Europe's plans to harness renewable energy and move towards a low carbon economy over the next twenty to fifty years. The creation of a pipeline with the ability to deliver 50GW of offshore wind by the Crown Estate in UK waters has propelled the UK to the forefront of this industry as a world market leader, attracting key companies from around the world to set up design and manufacturing facilities in the UK to serve this technology.

### Thin end of design

The engineering challenges that have arisen have resulted in less radical wind turbine design changes than expected. Although there have been a number of bold attempts to improve designs, such as the very large multi megawatt two-bladed turbines developed in the US and Europe in the 1980s, there has been critical factors acting on the business to stifle this vision.

- Lack of wide scale, well focused research and development funding in the early days, as wind energy was viewed as a fairly fringe activity compared to conventional power generation sectors.
- All wind turbines in commercial deployment are designed to act as standalone equipment despite rarely being cited in standalone situations. The opposite is actually true; they are predominately linked and interlinked to create the economies of scale required and to deliver suitable output.
- The changes in design that have been achieved in progressing the equipment to the sort of sizes demanded by the industry have resulted in comparatively very small changes in the overall design concept when reviewed against the engineering opportunity, although immense amounts of technological development have gone into the individual parts of wind turbines, and their associated electrical systems and control systems
- Probably the most obvious and significant wind turbine advancement is the size, the larger the blades, the greater the output being generated. Energy generated is directly proportional to the rotor diameter squared and the wind speed cubed.
- Offshore wind turbines are still, despite a reasonable number of cycles of evolution, largely marinised onshore designs, when considering the widely differing challenges presented offshore one would, from an engineering perspective, expect a larger divergence of technologies.
- Many of these challenges to the technological advancement of wind turbines, can be explained by the nature of the industry,

lack of well focused research and development funding and, from a western world perspective, a need to comply with the conservative nature of an industry driven by project finance and dogged with a litany of serial faults and industrial lack of coordination

Most wind farms currently running or projects in development are using current known technologies, better than the previous projects by conservative evolution rather than revolution, a little better and more efficient. Fuelled by financiers who are keen not to expose their assets to volatility or risk with an industry where the commercial and technical parameters on projects can be hugely variable and widely misunderstood

### Not necessarily without reason, Farmer DNA

The early industry adoption of one primary operating principle for both onshore and offshore energy requirements delivered a basic machine. Known and understood by the engineers, which could be benchmarked against known parameters to give a risk analysis for the financiers. However the generally chosen three bladed horizontal axis "Danish" design didn't perform particularly well in the early years when manufacture was in its infancy. There were a consistent number of failures in the earlier years with this technology due to manufacturing defects and lack of proper operation and maintenance procedures and understanding of site specific characteristics. This fuelled concerns about the practicality of looking to wind for our future needs against a very well understood nuclear and coal fired generation mix.

However, these mainstream turbines are now delivering consistent annual availabilities of 97,98 or even 99% per annum.

The move towards a whole new environment offshore has required revision



of the designs, building in additional redundancy of systems and building machines with longer maintenance intervals since it is not always possible to access offshore turbines for either scheduled or unscheduled maintenance. However these changes have largely been cosmetic when compared to the base design, whilst the fundamental concept remains untouched.

The cost and difficulty of getting service technicians to an offshore turbine is much greater than for the equivalent onshore machine. Similarly the cost of mobilising a crane barge or jack-up rig to change a major component offshore is much greater than a mobile crane for an onshore turbine. Current turbine designs are conventional, made more efficient and reliable by understanding the environment, loading statistics and in keeping up with the technological advances in components. But the basic machines have remained similar, enhancing the current products with subtle improvements in design such as control systems, condition monitoring of key components, improved blade pitching, improved yaw systems, and high tech materials.

### Future design drivers

However this will not be the case going forward. WHY? because we know so much more! we know how to deliver in harsh environments; we have c. 35 years of experience; we have tried and tested the current machinery. We know why it breaks. However there may be one overriding critical component which may have changed completely!

The infrastructures set up in the UK required bankers and financiers to drive the implementation of wind farms to make them reality. We had to pay for them somehow, and this was the way forward for the UK to have private investment to make it happen.

This all seems rather redundant now as the Asian rich economies pile into this space, harnessing our historic expertise together with our future visions, mixing it with their own visions, economic resources and expectation for growth and delivery in their fast paced culture.

The result will be the most technically advanced wind turbines, and possibly a revolution in design.

- **The Chinese industry** is less driven by structured finance than the UK and Europe and therefore able to innovate more. China will become the largest, most important region and coastline for the development of new wind technologies ready to directly supply their large coastal cities.
- **New design technologies** Offshore turbine development, growth and turbine advancement, vertical axis technology, drive train advancement, dc generation, streamlining & optimising the gearboxes and power electronics. The major limiting factors in onshore turbines such as noise, transport and logistics and overall size no longer apply offshore. Turbines can have two blades or even one blade and be just as efficient but much noisier, turbines can be virtually any size required and may go up 20MW sizes in the next few years. Rather than conventional AC generation, conversion to DC then transmission and rectification back to AC with large and complex offshore platforms it may

be possible to generate directly as DC, transmit to shore and then rectify.

- **More turbines** Designed to work as a group, with advanced, neural network actions to optimise output and more importantly with load balancing. Probably one of the biggest efficiency contributors will be driving the whole farm intelligently as a unit rather than an individual turbine.
- **Size matters** It costs less to manufacture, construct and maintain fewer larger turbines than smaller machines with the same combined rating. However overall capital costs of these larger offshore projects which are further out to sea and in deeper water have been escalating rapidly over the last few years. The early offshore projects that averaged £1M per MW installed has risen to in excess of £3M per MW installed at present. We wait to see whether volume and supply chain efficiencies can change this upward trend.

It is expected that up to 2014, the average rated power will be approximately the same as today, with the market being dominated by Siemens 3.6MW and the Vestas 3MW machines. It is expected that from 2015 onwards more turbines with ratings of 5-7MW will be installed in commercial offshore projects to leverage demand for installed capacity and lowering costs/unit of energy produced.

The average size of turbines will continue to increase over time, as manufacturers hone their competency and developers want higher yield and fewer costs. Design revolution may well happen towards the end of the three blade evolution as they strive for continuous performance and cost gains.

- **Innovation trimming for efficiency and longevity** Pitch regulation has advanced from stall machines to variable pitch fully variable generators, with load balancing. New machines are now starting to use some or all of the following advancements in technology:
  - Intelligent load control
  - Centralised functionality and optimised yaw control

- Multiple generators
- Managing wind flow more efficiently
- Sophisticated grid compatibility

- **Reliability** A key failure point with turbines is gearbox reliability which continues to dog the wind industry. As turbines become larger the push to improve performance becomes paramount. One company; Alstom, believes it has addressed the issue by ensuring that torque transmission is performed independently of rotor support. This improves the reliability of turbine drive train components, in particular the gearbox which is better protected and subjected to lower loads.

A study of more than 200 units of Alstom's 750kW wind turbines has shown a gearbox failure rate below 5% cumulated over the first nine years of operation. This number is remarkably low, and this statistic has the advantage of providing real life operation of the Alstom Pure Torque concept for longer periods than the megawatt class wind turbines.

So innovation is pushing up the reliability to well beyond the current 7 -11 years benchmark, which is still some way short of the expected design lifetime of 20 years for the turbine itself. And continues to add additional cost to developing and running wind farms in the current climate.

- **Environment** A significant expansion of wind power is planned in North Western Europe over the next few years, with increasing emphasis on offshore wind power. Currently, some 863 offshore wind turbines are operational here, but in excess of 10,000 are expected to be erected offshore in the next few years.

In order to maintain the credibility of the industry, we must utilise some of the vast opportunities in engineering advantage that are available to us whilst maintaining a circumspect and realistic perspective on the risks attributed to even the current generation of wind turbines. These when applied to onshore wind turbines are significant and should be carefully and professionally assessed.

When engineering aspects of wind turbines are examined the aggressive environment to which they are exposed should not be underestimated. All other structures which are put in this position have a large amount of their design effort concentrated on minimising the loads applied to them not only from wind, but also waves, tides, seabed mobility, etc.

Our design basis for wind turbines starts with the desire to capture as much of the available wind forces as possible. This can result in some impressive forces which dwarf the loads and forces experienced in most other industries. The tips of the blades of a large turbine weigh in excess of 15t each and travel in excess of 200mph, whilst the overturning moment the wind turbine has to resist, purely from the forces applied by the wind, is the equivalent of a double decker bus on the end of an unsupported cantilever more than a mile long. Also since the wind is constantly varying both in strength and direction, this is the equivalent of the bus being bounced up and down on some very irregular road surface.

On this basis, as an industry we should not be too scathing as to how far we have progressed over the last 30 years in bringing wind turbine technology to where it is today, however the variation in equipment, environment in which we are placing it and the way it is used varies dramatically, so careful planning, design, implementation and operation is vital to achieving the expected outcome.

### Conclusion

From an immature market and the conversion of a water pump, wind farm technology as an energy producer has been incredibly well received by large global communities who are already adopting this technology into their own energy requirements. This technology will allow countries to develop a clean energy source going forward. Technology and expertise will redefine the componentry through continued product innovation and development, and we hope, some technical revolution along the way.

**Many thanks to.....at PMSS.**