Renewable Energy

Wind-Power Technology

Emerging Innovative Wind-Power Technology

White Paper

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Revision

Change Record

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None

Status and Purpose

The objective of this White Paper is to provide an overview of :

- Wind Power technology market size
- Dominant technology trends
- Emerging technology trends

With the purpose of sharing an insight of opportunities of emerging wind power technology and current status of conventional dominant technologies.

Executive Summary

The various strategies of dealing with limitations of the dominant technology approach a near-end scenario stretching current capabilities of the underlying supporting technology(e.g. lighter material composites) compromising the development of new cost-effective products. Examples, such as an increase of the wind turbine power ratings beyond 15–20 MW's require yet unreliable light weight mechanical components which are still not available, and the low torque shaft design improvements which requires large scale costly experimentation/

The ample opportunities of low speed wind energy designs avoid the constrains of blade efficiency problems exploiting the current available supporting technology platforms, without heavy large-scale investments in basic research and costly R&D projects.

The advantages for emerging new alternative wind-power technologies resides in:

- the robust and growing wind-energy market,
- the high-costs in developing cost-effective solutions of conventional technology,
- the technological competition strength away from limitations of conventional designs and
- the low entry cost to deliver a competitive workable product.

Current Wind Energy Market

The cumulative installed wind power capacity increased exponentially from 6100 megawatt (MW) in 1996 to 282.6 GW in 2012 and 650.8 GW in 2020(1) It is anticipated that, despite the temporal economy slowdown due to COVID19 scenario and other influential energy market changer such as the collapse of the oil market, the cumulative wind capacity would reach 750 GW by 2021. The average rate of yearly investment in new wind power is 45 GWs per year equivalent to Euros 56 billion.

Approximately 24 countries have more than 1 GW cumulative installed wind power capacity, including 16 in Europe, 4 in the Asia-Pacific area (China, India, Japan, Australia), 3 in North America (Canada, Mexico, US) and 1 in Latin America (Brazil).

(1)

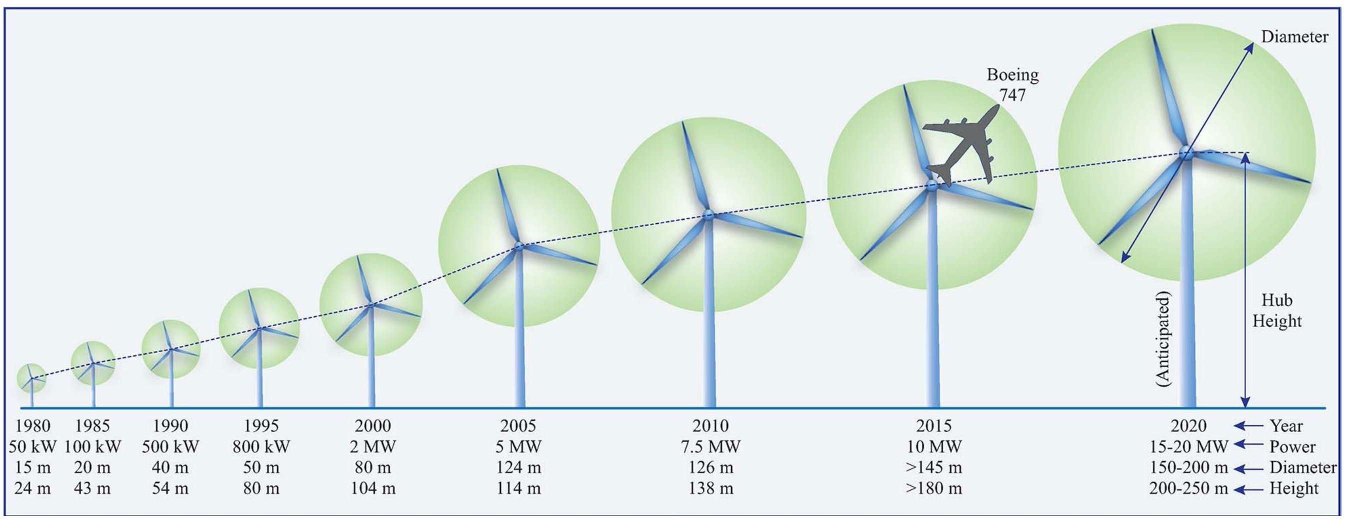

Fig. 1. Evolution in the size of commercial wind turbines.

Rotor type of Generator/ converter configurations are still the dominant player in the wind energy market. However, due to innate technological limitations of the dominant technology in specific design areas, namely:

- Limited modularity due to height/power ratio
- Maintenance cost/ reliability due to height
- converter complexity due to large dimensions
- control complexity due to sizing and protection systems
- control strategy limitations
- voltage stress due to high voltage at peak power
- increasingly high operation voltage due to demand
- limitations of achievable power levels due to power/ cutoff speed.

In the following sections, this White Paper discusses how the various strategies of dealing with limitations of the dominant technology approach a near-end scenario stretching current capabilities of the underlying supporting technology(e.g. lighter material composites) compromising the development of new cost-effective products.

This scenario offers uncounted opportunities for alternative less size-biased wind generator technologies such as the ones exploiting other operating conditions.

- Low wind speed alternative generator devices and
- Wind speed and direction-oriented control strategies, (which can be exploited at the current technology development only at low wind speed conditions)

The following examination provides an insight of the strengths and advantages of emerging wind-power technology compared to conventional rotor-blade designs.

Dominant Technology Limitations

Mechanical technologies are major drivers of today's practical development of multi-megawatt wind turbines and they are also the source of major limitations and dependency with supporting technology developments.

Gearbox and Drive-Train Technologies

The mechanical components such as blades, gearbox and tower are the main restriction for power levels beyond 15–20 MW.

To increase the wind turbine power ratings beyond 15–20 MW's, the wind industry must develop light weight mechanical components which are still not available.

Due to the increasing large dimensions and weight of the proposed new generation turbines, technology advancements tend to stall until new materials, in particular, lighter high expensive composites and large-size-capable advanced rotor shaft optimization and power transmissions are developed.

The low torque shaft problem requires large scale experimentation and costly research facilities to unleash relatively small improvements that can translate into output power and palatable power/cost ratios to the end-user.

It is expected that direct drive technology may help reduce the maintenance requirements in offshore wind turbines. Currently, direct drive wind turbines contribute to over 28% of the global market share and they continue to dominate the future of dominant conventional turbine technology.

Similarly, multiple drive train technology may help reduce the mechanical torque on each generator shaft. Innovations in drive train technology will also contribute to boosting the wind turbine power ratings further.

Turbine Blades

Wind turbine blades are the most distinctive, visible and crucial components of turbine generators which have evolved rapidly in terms of aerodynamic design and materials. The most commonly used materials in the modern wind turbines are aluminum, fiberglass, polyester resin, light wood or carbon-fiber composites.

Blades requirements such as

- lighting protection,
- noise reduction,
- optimum shape,
- higher power-to-area ratio and
- easy manufacturing

all the above requirements impose a great challenge to the turbine manufacturers.

The recent developments in the blade "sandwich" technology shows improvements in lowering manufacturing and transportation costs.

However, wind turbine blades have a maximum aerodynamic efficiency of 59% according to the Betz limit.

The highest aerodynamic efficiency achieved to date is 50%

- Enercon,
- Shandong SwissElectric and
- Wikov blades

The ample opportunities of low speed wind energy designs avoid the constrains of blade efficiency problems exploiting the current available supporting technology platforms, without heavy large-scale investments in basic research and costly R&D projects.

Tower Foundations On & Off Shore

Wind turbine foundations directly support the tower and rotor blades.

The foundations of onshore turbines are simple and it includes slab, monopile and multiple combined types. The depth and increasing soil mechanical property requirements aggravated by size, weight and increasing cutoff wind conditions of conventional rotor blade technology pushes installations towards exploring sea-level near shore and off shore installations.

In off-shore environments, different water depths and soil types, and harsh weather conditions, move the design of foundations for offshore wind turbines to quite challenging engineering design exercises. The problem triggered multiple costly research and development activities intended to optimize offshore foundation concepts, such as gravity, monopile, tripod, tri-pile, jacket and floating.

The gravity and monopile foundations are applicable for shallow waters with depth less than 30 m. Other foundations especially floating foundations which have already been used in offshore oil and gas industry may be a target of investments of promising future deep water (> 40 m) projects.

However, R&D costs and chances of cost-effective success in the field of on-shore and, even more challenging, off-shore foundation solutions for rotor-blade large scale generators brings the opportunities for technological advancements to unprofitable propositions.

Integration to Power Systems

The integration of wind turbines to power system is increasingly an area of concern and attention in the near future. Wind farms performance and operation capabilities in supply security, reliability and power quality are critical parameters to consider for power system operators.

Grid code requirements for frequency support, active and reactive power control, short-circuit power level, voltage variations, flicker, harmonics and stability become pillars of standard regulations in today's new country-level regulations in the arena of wind-power generators.

It is anticipated that additional requirements continue to be added and have significant impact on the design and operation of modern high- power wind turbines.

Asymmetrical grid fault conditions caused by coexisting generator-converter technologies become the new challenge for the wind generation systems. Full-scale voltage source converters meet requirements at affordable performance cost ratios, however current source converters and partial scale voltage source converters require specific features which find extreme conditions earlier as size and high-power products enter in the market.

The competition environment in large-power rotor-blade wind turbine products is currently favoring mega Corporations, which can afford costly R&D investments for achieving increasingly slimmer performance/cost ratios.

Wind-Power Tech Evolution

From limited designs, country-side beginnings and poor performance products wind turbines have incredibly progressed in every aspect of the industry, creating an entire solid market ecosystem of growing opportunities and undoubtedly bright future.

The introduction of global initiatives to combat climate change, such as the Paris Agreement brought the necessary platform to take serious efforts and attracted multiple market players .

Wind-power energy is now growing exponentially driving in just 15 years from 2000 to 2015, a cumulative worldwide wind capacity of 17,000 megawatts to more than 430,000 megawatts.

China surpassed the European Union in the number of installed wind turbines in year 2015, and leads most of the scale projects and R&D investments.

Current industry specialized SME’s anticipate that by 2050 one third of the world's electricity will be based on wind power sources, a mark that took the world the surprising time of largely more than 50 years to achieve.

The entire success behinds the history of wind energy generators, as for many other similar technologies, relies on progressive incremental improvements departing from relatively simple governing principles.

The advantages for emerging new alternative wind-power technologies resides in :
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